COSEWIC
Assessment and Status Report

on the

Eastern Musk Turtle
Sternotherus odoratus

in Canada

SPECIAL CONCERN
2012

COSEWIC
Committee on the Status
of Endangered Wildlife
in Canada

COSEPAC
Comité sur la situation
des espèces en péril
au Canada

COSEWIC status reports are working documents used in assigning the status of wildlife species suspected of being at risk. This report may be cited as follows:

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COSEWIC
Assessment Summary

Assessment Summary – November 2012

Common name
Eastern Musk Turtle

Scientific name
Sternotherus odoratus

Status
Special Concern

Reason for designation
This species occupies shallow waters of lakes, rivers, and ponds. In southwestern Ontario, the species has declined substantially and is now restricted to a few tiny, scattered populations. Throughout its Canadian range, this species is vulnerable to increased mortality of adults and juveniles from recreational boating, development and loss of shoreline habitat, and fisheries by-catch. The species has delayed maturity and a low reproductive rate with a small clutch size. Since the previous assessment in 2002, increased survey effort has found more populations in eastern Ontario and adjacent areas of Quebec. The species distribution range remains unchanged, but losses in the southern half of its range make it near Threatened.

Occurrence
Ontario, Quebec

Status history
Designated Threatened in May 2002. Status re-examined and designated Special Concern in November 2012.

COSEWIC
Executive Summary

Eastern Musk Turtle
Sternotherus odoratus

Wildlife Species Description and Significance

The Eastern Musk Turtle, *Sternotherus odoratus*, is a small freshwater turtle with a narrow, domed carapace, and a large head with a pointed snout. Two yellow/white stripes extend from the nose, above and below the eyes, and along the sides of the head and neck. These stripes are not always apparent on older individuals. The plastron is small and cross-shaped. There are two or more pointed barbels present on the chin and throat. Individuals may strike defensively when handled and are often called 'Stinkpots' because of the musky odour they exude. The Eastern Musk Turtle was first described in 1802 by P.A. Latreille and it is the only representative of the family Kinosternidae in Canada.

Distribution

The Eastern Musk Turtle is restricted to eastern North America. The species ranges from Florida, north to Ontario and Québec, and west to Wisconsin and central Texas. Approximately 5 % of the global range of the Eastern Musk Turtle extends into Canada. In Canada, the Eastern Musk Turtle is found in southern Ontario, the southeastern edge of northeastern Ontario and the southwestern edge of Québec.

Habitat

The Eastern Musk Turtle is a highly aquatic species inhabiting littoral zones of waterways such as rivers, lakes, bays, streams, ponds, canals, and swamps with slow to no current and soft bottoms. During their active season, Eastern Musk Turtles prefer shallow water (depth < 2 m) with abundant floating and submerged vegetation. Individuals are most often found close to shore and usually do not venture onto land except to nest or to access adjacent wetlands. Nest sites are generally located 3 to 11 m from shore and eggs are typically laid in shallow excavations in sand, at the base of dune grasses, decaying vegetable matter, rotting wood, and in the walls of Muskrat or Beaver lodges. Suitable Eastern Musk Turtle habitat is abundant across Central and Eastern Ontario, especially in the Canadian Shield Region.

Biology

The Eastern Musk Turtle is chiefly crepuscular and, in Canada, is active from late April to early October. They often bask near the water's surface under lily pads, other floating vegetation, and debris and rarely venture or bask out of water.

Longevity in wild populations is >30 years and generation time is 14-20 years. In Canada, sexual maturity is reached between 5 and 6 years by males and 8 and 9 years by females. Mating activity peaks in spring (April – May) and fall (September – October) when turtles congregate at hibernation sites. Multiple paternity is possible and, typically, a clutch has 3 to 7 eggs. Eggs are laid in June and July and hatchlings emerge in August and September. Females may exhibit year-to-year nest site fidelity and, generally, more than one female will nest in the same area. The temperature regime in the nest determines the sex of the offspring.

The Eastern Musk Turtle is a bottom-feeding omnivore. Eggs, hatchlings, juveniles and adults of Eastern Musk Turtles are eaten by many predators, including Raccoons, Striped Skunks, herons, crows, foxes, predatory fish, predatory birds, American Bullfrogs, Northern Watersnakes, Snapping Turtles and Fishers.

In general, daily movements are limited to 25-131 m per day. Annual home ranges at Canadian sites range from 0.08 to 430 ha. Long-distance travel (> 1 km) usually occurs overnight and dispersal is most likely achieved via aquatic corridors. Populations are considered isolated if they are separated by more than 10 km of riverine habitat, 5 km of other aquatic habitat, and 1 km of land. Furthermore, roads, locks and dams, rugged terrain, salt water and inhospitable land uses limit movement between habitat fragments.

Population Sizes and Trends

The Canadian population of Eastern Musk Turtles occurs in over 100 sites scattered across southern and central Ontario and southwestern Québec. Population size estimates have been carried out on only five sites in Canada: Grenadier Island (St. Lawrence River), Loon Island (Georgian Bay), Massasauga Provincial Park (Georgian Bay), Norway Bay (Ottawa River) and Point Pelee National Park (Lake Erie). Eastern Musk Turtle population size estimates for these sites vary from 84 to over 1400 individuals.

In Ontario, declines in some Eastern Musk Turtle populations have been observed and, in more remote locations, are inferred based on known threats (e.g., fisheries bycatch). Of the 32 census divisions in Ontario and Québec that have recorded sightings, 8 (28 %) have had no reported sightings since 1986. Historical populations mostly in southern Ontario (e.g., Thames River, Rondeau Bay, Long Point) that have survey efforts yielding no sightings plus high habitat conversion rates in surrounding areas are likely extirpated or non-viable. However, lack of recent sightings may not reflect decline or extirpation in areas with limited recent survey efforts, abundant habitat and no major threats.

Threats and Limiting Factors

The most significant threats to Eastern Musk Turtle populations in Canada are fisheries bycatch and habitat destruction and alteration (e.g., land conversion, shoreline development, dam placement, dredging and draining of waterways and wetlands). Given this species' low adult recruitment and delayed sexual maturity, chronic added mortality of juveniles and adults (particularly females) could eliminate local populations. Added sources of juvenile and adult mortality can stem directly and indirectly from human recreational activities (i.e., fishing, power boating) and urbanization (i.e., roads, subsidized predators). Due to the aquatic nature of Eastern Musk Turtles, most added anthropogenic sources of mortality are linked to aquatic activities. Other long-term threats to Eastern Musk Turtles are illegal collection, habitat alteration by non-native species, and, potentially, decreased reproductive success due to environmental contamination.

Protection, Status, and Ranks

In Canada, the Eastern Musk Turtle is ranked 'Vulnerable' (N3) by NatureServe and was assessed as 'Threatened' by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) in 2002. In Ontario, the Eastern Musk Turtle is ranked 'Vulnerable' (S3) by NatureServe and was assessed as 'Threatened' by the Committee on the Status of Species at Risk in Ontario (COSSARO). In Québec, the Eastern Musk Turtle is ranked 'Critically Imperiled' (S1) in NatureServe and was assessed as 'Threatened' by the 'Ministère des ressources naturelles et de la Faune' (MRNF). The General Status of Species in Canada gives it a rank of 'At Risk' nationally and for each of Ontario and Quebec.

Persecution and habitat destruction are regulated under the federal *Species at Risk Act* (2003), the Ontario *Endangered Species Act* (2007), the 'Loi sur les espèces menacées ou vulnerables' (1989) in Québec, and the 'Loi sur la conservation et la mise en valeur de la faune' (2002) in Québec. Hunting and trapping of this species are regulated under the Ontario *Fish and Wildlife Conservation Act* (1997) and the 'Loi sur la conservation et la mise en valeur de la faune' (2002) in Québec. Approximately 17% of areas where Eastern Musk Turtles are known to occur in Canada are in protected areas.

TECHNICAL SUMMARY

Sternotherus odoratus
Eastern Musk Turtle — Tortue musquée
Range of occurrence in Canada: ON, QC

Demographic Information

Generation time: Mitchell (1988) reported annual mortality at 0.16, but this study was in a pond in Virginia, and it is possible that the annual rate of mortality in Canadian populations is significantly lower than in that study. Edmonds (1998) reported annual mortality at 0.09. Both estimates are maxima as not all turtles not recaptured would have died. Therefore, generation time may be 14 - 20 years or longer. (see **BIOLOGY – Growth and Longevity**) GT = 1/adult mortality + age of first reproduction (IUCN 2010a) GT= 1/0.16 + 8 = 14 years (based on Mitchell 1988), or GT = 1/0.09 + 9 = 20 years (based on Edmonds 1998).	14 - 20 years *See* **BIOLOGY – Growth and Longevity**.
Is there an observed, inferred, or projected continuing decline in number of mature individuals? Certain populations south of the Canadian Shield are believed to be extirpated from their historical locations based on negative survey results and habitat loss. Ongoing and projected loss of habitat suggests that declines of mature individuals will continue into the future.	Yes, observed, inferred, and projected decline.
Estimated percent of continuing decline in total number of mature individuals within 5 years or 2 generations (28 - 40 years).	Unknown; likely to be high south of the Canadian Shield.
Observed, estimated, inferred or suspected percent reduction in total number of mature individuals over the last 3 generations (42 - 60 years). Some populations are believed to be extirpated from their historical locations based on negative survey results and habitat loss, but exact numbers are unknown.	Unknown; reduction observed and substantial reduction inferred south of the Canadian Shield. Declines are inferred in populations elsewhere when there is extensive, shoreline development, recreational boating or commercial fishing.
Projected or suspected percent reduction in total number of mature individuals over the next 3 generations (42 - 60 years).	Unknown; significant reduction suspected if threats are not addressed.
Observed, estimated, inferred, or suspected percent reduction in total number of mature individuals over any 3 generations period, including both the past and the future. Percent reduction in the past is suspected to be high in areas south of the Canadian Shield due to loss of habitat and habitat fragmentation in areas where Eastern Musk Turtle were reported to occur historically. Significant reduction is suspected in the future if threats are not addressed. Potentially, the species has been lost from 28-34 % of historical census divisions.(see: POPULATION SIZES AND TRENDS; Fluctuations and Trends)	Significant reduction (~30 %?) suspected due to continuing habitat loss and fragmentation.
Are the causes of the decline clearly reversible and understood and ceased?	Major causes are understood but not ceased. Causes of decline in southern Ontario may not be understood.

Are there extreme fluctuations in number of mature individuals?	No

Extent and Occupancy Information

Estimated extent of occurrence*	
Recent Sighting Records (Post-1986)	141 026 km^2
All Sighting Records	170 617 km^2
**Recent Sighting Records (Post-1986) (< 500 m from shoreline in Great Lakes)	123 481 km^2
**All Sighting Records (< 500 m from shoreline in Great Lakes)	132 205 km^2
**All estimates were limited to Canada's extent of jurisdiction* ***Estimates exclude open water in the Great Lakes further than 500 m from land.*	*See* **DISTRIBUTION – Canadian Range.**
Index of area of occupancy (IAO)	
Recent Sighting Records (Post-1986)	1060 km^2
All Sighting Records	1408 km^2
Sightings reported prior to 1986 cannot be inferred to be historical without specific survey and habitat data for this species, thus the values presented above are simply an estimate of potential reduction in IAO.	*See* **DISTRIBUTION – Canadian Range.**
Is the total population severely fragmented*? Overall, the Canadian population of Eastern Musk Turtles is not severely fragmented as only 38% of IAO patches are isolated. At the regional level, however, fragmentation can be considered severe in southwestern Ontario (69%) and the Golden Horseshoe (75%) because over 50% of IAO patches in these areas support only small populations and are separated by large distances across highly altered landscapes. Therefore, these populations have low viability. **Used the IUCN definition for severe fragmentation (IUCN 2001) in combination with Eastern Musk Turtle dispersal ability**	No; however populations in southwestern Ontario and the Golden Horseshoe specifically, may be severely fragmented. *See* **HABITAT – Habitat Trends**
Number of locations	
Recent Sighting Records (Post-1986)	77
All Sighting Records	113
Locations are based on Eastern Musk Turtle sighting records and the IUCN definition for locations.	*See* **POPULATION SIZES AND TRENDS - Abundance**
Is there an observed continuing decline in extent of occurrence?	Yes
Is there an observed continuing decline in index of area of occupancy?	Yes

Is there an observed continuing decline in number of populations? Twenty-eight per cent of census divisions where Eastern Musk Turtles were recorded prior to 1986, mostly in southern Ontario, have not had any recent reported sightings (post-1986) (Table 1). Combined with negative survey results and habitat loss and alteration, several of these historical southern Ontario populations are believed to be extirpated. Other historical populations adjacent to highly developed areas may also be extirpated, based on a lack of recent sighting reports and high land conversion rates over the last 25 years, but no conclusions can be made at this time as no recent surveys have been carried out in these areas.. **Since the last COSEWIC status report, however, 36 new populations have been identified due to increased search effort.*	Yes *See* **POPULATION SIZES AND TRENDS – Fluctuations and Trends**
Is there an observed continuing decline in number of locations? Some historical locations of Eastern Musk Turtles in southern Ontario are believed to be extirpated based on negative survey results. Other historical locations adjacent to highly developed areas may also be extirpated, based on a lack of recent sighting reports and high land conversion rates over the last 25 years, but no conclusions can be made at this time as no recent surveys have been carried out in these areas. Thirty-four per cent of census divisions where Eastern Musk Turtles were observed prior to 1986 have had few or no recent reported sightings (post-1986). **Since the last COSEWIC status report, however, there has been an increase in the number of locations identified due to increased search effort*	Yes *See* **POPULATION SIZES AND TRENDS – Fluctuations and Trends**
Is there an observed, inferred, or projected continuing decline in area, extent and/or quality of habitat?	Yes, observed and projected.
Are there extreme fluctuations in number of populations?	No
Are there extreme fluctuations in number of locations?	No
Are there extreme fluctuations in extent of occurrence?	No
Are there extreme fluctuations in index of area of occupancy?	No

Number of Mature Individuals (in each population)

Population, Year of Estimate	N Mature Individuals
1. Point Pelee, 2003	< 84 ± 76.8
2. Grenadier Island (part of a population in the Thousand Islands region), 2008	< 241 (95% C.I.: 207 - 341)
3. Loon Island (part of the Georgian Bay South-East population), 1997	441 (95% C.I.: 256 - 513)
4. Massasauga Provincial Park (part of the Georgian Bay South-East population), 2009	1440 ± 633
5. Norway Bay (part of a population in the Ottawa River), 2006	< 295 (95% C.I.: 206 - 467)
6. All other populations	Unknown
Total	Likely > 10,000 **See POPULATION SIZES AND TRENDS - Abundance**

Quantitative Analysis

Probability of extinction in the wild	N.A.

Threats (actual or imminent, to populations or habitats)

1) Habitat destruction, alteration, and fragmentation (actual)
2) Chronic juvenile and adult mortality (e.g., fisheries bycatch, boat hull impacts/ propeller injuries, road mortality, subsidized predators) (actual)
3) Increased nest predation (e.g., subsidized predators) (actual)
4) Illegal harvesting (e.g., pet trade, private collection) (actual)
5) Pollution (actual)
6) Non-native species (actual)
7) Disease (potential)
8) Global climate change (potential)

Rescue Effect (immigration from outside Canada)

Status of outside population(s)? USA: N5; common across most of its American range, including two of the three adjacent states (Michigan and New York) but ranked vulnerable in Vermont (AL-S5, AR-S5, CT-S4, DC-S4, DE-S5, FL-S5, GA-S5, IA-S2, IL-S5, IN-S4, KS-S4, KY-S5, LA-S5, MD-S5, MA-S4S5, ME-S3, MI-S5, MS-S5, MO-S5, NH-S5, NJ-S5, NY-S5, NC-S5, OH-SNR, OK-S4, PA-S4, RI-S4, SC-SNR, TN-S5, TX-S5, VA-S5, VT-S2, WI-S4, WV-S5).	
Is immigration known or possible?	Possible from Michigan, Vermont and New York.
Would immigrants be adapted to survive in Canada?	Likely, because they exist in the same climatic regions.
Is there sufficient habitat for immigrants in Canada?	Likely
Is rescue from outside populations likely?	Unlikely

Status History

COSEWIC: Designated Threatened in May 2002. Status re-examined and designated Special Concern in November 2012.

Status and Reasons for Designation

Status: Special Concern	**Alpha-numeric code:** Not applicable

Reasons for designation:

This species occupies shallow waters of lakes, rivers, and ponds. In southwestern Ontario, the species has declined substantially and is now restricted to a few tiny, scattered populations. Throughout its Canadian range, this species is vulnerable to increased mortality of adults and juveniles from recreational boating, development and loss of shoreline habitat, and fisheries by-catch. The species has delayed maturity and a low reproductive rate with a small clutch size. Since the previous assessment in 2002, increased survey effort has found more populations in eastern Ontario and adjacent areas of Quebec. The species distribution range remains unchanged, but losses in the southern half of its range make it near Threatened.

Applicability of Criteria

Criterion A (Decline in Total Number of Mature Individuals): Not applicable. Declines have probably occurred over the past three generations (40+ years); however, there are few quantitative data to estimate the size of this decline precisely although the amount of decline almost meets threatened A2b.
Criterion B (Small Distribution Range and Decline or Fluctuation): Not applicable. Meets Threatened B2 (IAO < 2000km^2) b(ii,iii,v) but does not meet severe fragmentation (a) or extreme fluctuations (c).
Criterion C (Small and Declining Number of Mature Individuals): Not applicable. Population is declining but probably exceeds 10,000 mature individuals.
Criterion D (Very Small or Restricted Total Population): Not applicable. Population >> thresholds.
Criterion E (Quantitative Analysis): Not done.

PREFACE

Several Eastern Musk Turtle surveys have been completed in Ontario and Québec since the last status report in 2002 and 36 new Eastern Musk Turtle 'populations' (32% of all Eastern Musk Turtle 'populations' based on reported sightings) have been identified. This increase is unlikely to represent an increase in abundance or range, but rather it reflects turtles that have historically been in these areas yet remained undetected or unreported. In Ontario, declines in Eastern Musk Turtle populations have been observed (southwestern Ontario and Golden Horseshoe) and, in more remote locations, are inferred based on the presence of known threats (e.g., fisheries bycatch, recreational boating). Of the 29 census divisions in Ontario that have recorded sightings, eight (28%) have had no reported sightings since 1986. Combined with survey efforts yielding no sightings and high habitat conversion rates in surrounding areas, these findings suggest that certain historical populations of this species may be extirpated or nonviable, most noticeably populations in the Golden Horseshoe (i.e., Hamilton) and southwestern Ontario (i.e., Thames River, Rondeau Bay, Long Point). Due to the somewhat cryptic nature of Eastern Musk Turtle, however, lack of recent sightings alone does not necessarily reflect declining populations or extent of occurrence in areas where, despite no recent survey efforts, habitat is abundant and there is little human disturbance (e.g., Georgian Bay, eastern Ontario). In such areas, if no major threats exist (i.e., high adult mortality due to direct and indirect anthropogenic activities), populations are most likely stable. There are not enough data to determine Eastern Musk Turtle population trends in Québec. Major threats to persistence of Eastern Musk Turtles in Canada are habitat destruction and alteration, habitat fragmentation, chronic anthropogenic sources of mortality (e.g., fisheries bycatch, boat hull impacts/ propeller injuries, added nest predation by subsidized predators), and illegal collection. The draft Canadian Multi-Turtle Recovery Strategy (Ontario and Québec) is currently under review and a document outlining criteria to identify Critical Habitat for Eastern Musk Turtles is being prepared. In Ontario, a draft Multi-Species Turtles at Risk Recovery Strategy has been prepared. In Québec, a Recovery Plan for Five Turtle Species, including the Eastern Musk Turtle, has been published and implemented since 2006. Approximately 17% of areas where Eastern Musk Turtles occur in Canada are currently found within protected areas.

The Eastern Musk Turtle was downlisted from Threatened to Special Concern despite there being no evidence that its situation has improved since the previous status assessment. The likely reason for the downlisting is that many "new" populations were discovered in the past decade. These populations were undoubtedly present at the previous assessment, but were unknown then, and were discovered by extensive targeted surveys stimulated by the Threatened status assessed in 2002.

COSEWIC HISTORY

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) was created in 1977 as a result of a recommendation at the Federal-Provincial Wildlife Conference held in 1976. It arose from the need for a single, official, scientifically sound, national listing of wildlife species at risk. In 1978, COSEWIC designated its first species and produced its first list of Canadian species at risk. Species designated at meetings of the full committee are added to the list. On June 5, 2003, the *Species at Risk Act* (SARA) was proclaimed. SARA establishes COSEWIC as an advisory body ensuring that species will continue to be assessed under a rigorous and independent scientific process.

COSEWIC MANDATE

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) assesses the national status of wild species, subspecies, varieties, or other designatable units that are considered to be at risk in Canada. Designations are made on native species for the following taxonomic groups: mammals, birds, reptiles, amphibians, fishes, arthropods, molluscs, vascular plants, mosses, and lichens.

COSEWIC MEMBERSHIP

COSEWIC comprises members from each provincial and territorial government wildlife agency, four federal entities (Canadian Wildlife Service, Parks Canada Agency, Department of Fisheries and Oceans, and the Federal Biodiversity Information Partnership, chaired by the Canadian Museum of Nature), three non-government science members and the co-chairs of the species specialist subcommittees and the Aboriginal Traditional Knowledge subcommittee. The Committee meets to consider status reports on candidate species.

DEFINITIONS
(2012)

Wildlife Species	A species, subspecies, variety, or geographically or genetically distinct population of animal, plant or other organism, other than a bacterium or virus, that is wild by nature and is either native to Canada or has extended its range into Canada without human intervention and has been present in Canada for at least 50 years.
Extinct (X)	A wildlife species that no longer exists.
Extirpated (XT)	A wildlife species no longer existing in the wild in Canada, but occurring elsewhere.
Endangered (E)	A wildlife species facing imminent extirpation or extinction.
Threatened (T)	A wildlife species likely to become endangered if limiting factors are not reversed.
Special Concern (SC)*	A wildlife species that may become a threatened or an endangered species because of a combination of biological characteristics and identified threats.
Not at Risk (NAR)**	A wildlife species that has been evaluated and found to be not at risk of extinction given the current circumstances.
Data Deficient (DD)***	A category that applies when the available information is insufficient (a) to resolve a species' eligibility for assessment or (b) to permit an assessment of the species' risk of extinction.

* Formerly described as "Vulnerable" from 1990 to 1999, or "Rare" prior to 1990.

** Formerly described as "Not In Any Category", or "No Designation Required."

*** Formerly described as "Indeterminate" from 1994 to 1999 or "ISIBD" (insufficient scientific information on which to base a designation) prior to 1994. Definition of the (DD) category revised in 2006.

Environment Canada Environnement Canada
Canadian Wildlife Service Service canadien de la faune

Canada

The Canadian Wildlife Service, Environment Canada, provides full administrative and financial support to the COSEWIC Secretariat.

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2012

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Appendix 2. Index of area of occupancy (IAO) of the Eastern Musk Turtle in Canada using both recent and historical sightings and a 2 x 2 km grid. The IAO calculation and the corresponding map were provided by Jenny Wu, Environment Canada, 2012. 68

WILDLIFE SPECIES DESCRIPTION AND SIGNIFICANCE

Name and Classification

Class:	Reptilia
Order:	Testudines
Family:	Kinosternidae
Genus:	*Sternotherus*
Species:	*Sternotherus odoratus* (Latreille, 1802)

Common name:
English: Eastern Musk Turtle, Common Musk Turtle, Stinkpot.
French: Tortue musquée.

The Eastern Musk Turtle (*Sternotherus odoratus*) was first described in 1801 based on a specimen from South Carolina and was named *Testudo odorata* by Latreille (Latreille 1802). Since then, this turtle has received six other scientific names: *Sternotherus odoratus, Sternothaerus odoratus*, *Aromochelys odoratus*, *Aromochelys carinatus nec*, *Kinosternon odoratus,* and *Kinosternon odoratum* (Vogt 1981). Although a study by Iverson (1991a), using morphological characters, suggests that the Eastern Musk Turtle be placed in the genus *Kinosternon* and renamed *Kinosternon odoratus*, most herpetologists, including Iverson, still use the scientific name *Sternotherus odoratus* (Edmonds and Brooks 1996; Iverson 1998; Ernst and Lovich 2009; Picard *et al.* 2011; Crother 2012).

The Eastern Musk Turtle is a member of the family Kinosternidae, which is composed of four genera and 25 species (Rhodin *et al.* 2010). Four species make up *Sternotherus*: *S. carinatus*, *S. depressus*, *S. minor* and *S. odoratus*. The only representative of the family Kinosternidae that ranges into Canada, however, is the Eastern Musk Turtle (Ernst and Lovich 2009). Relationships among the *Sternotherus* species are unclear. Electrophoresis (Seidel *et al.* 1981) and DNA (Iverson 1998) suggest the Eastern Musk Turtle is most closely related to *S. carinatus*, but morphological characters suggest it is more closely related to *S. depressus* and *S. minor* (Iverson 1991a). Within the turtle evolutionary tree, Barley *et al.* (2010) found strong support for a clade consisting of sea turtles, mud and musk turtles, and Snapping Turtles (Chelydridae). Within this clade, Snapping Turtles (Chelydridae) and mud/musk turtles (Kinosternidae) are sister taxa (Barley *et al.* 2010).

Morphological Description

The Eastern Musk Turtle is small freshwater turtle with a narrow, domed carapace, and a large head with a pointed snout (Figure 1). The carapace can be grey, brown or black and is sometimes streaked or spotted with dark pigment. Often covered in algae, the carapace of adults is smooth. The plastron is small, cross-shaped, composed of 11 scutes, yellowish or brownish, and has a single inconspicuous hinge. Often there are patches of smooth skin present between the scutes of the plastron. The skin colour can vary from pinkish-gray to black and there are two or more pointed barbels present on the chin and throat. Two yellow/white stripes extend from the nose, above and below the eyes, and along the sides of the head and neck (Figure 1); these stripes are not always apparent on older individuals (Ernst and Lovich 2009), often appearing mottled.

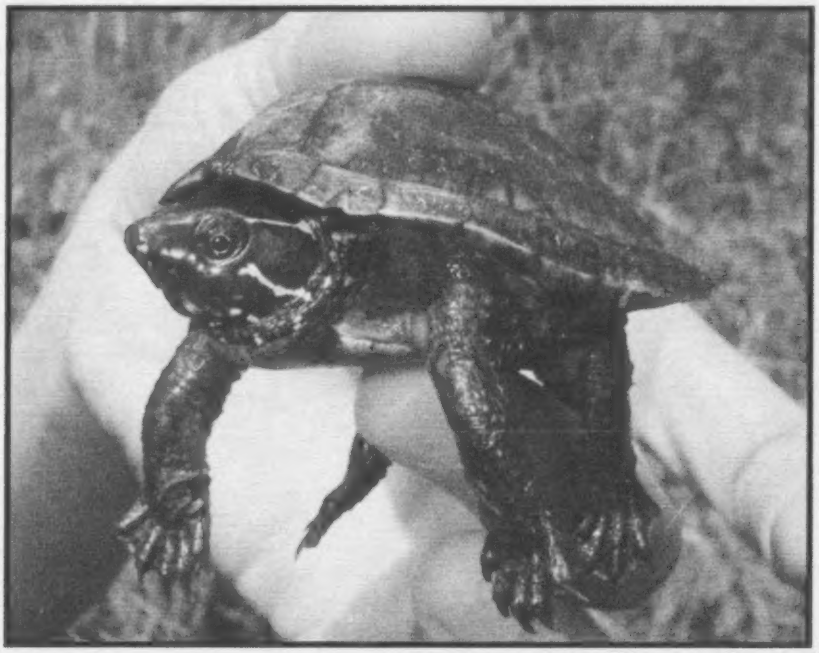

Figure 1. Eastern Musk Turtle, *Sternotherus odoratus*. (Photo credit: Dr. Gabriel Blouin-Demers)

Males have longer tails which end in a blunt terminal nail and two patches of rough scales on the inner side of each hind leg (Gross 1982; Cook 1984). The sexes are similar in size and adult carapace lengths rarely exceed 13 cm (Harding 1997). Straight line carapace length is clinal, with larger individuals in the north and smaller individuals in the south (Tinkle 1961; Edmonds and Brooks 1996; Ashton and Feldman 2003).

The carapace of hatchlings and juveniles is black, rough in texture, and has a prominent vertebral keel. In addition to the vertebral keel, hatchlings also have two smaller lateral keels and a white spot on the outer edge of each marginal scute. The skin is black and the two light stripes on the head are prominent (Ernst and Lovich 2009).

Individuals of this species are often called 'Stinkpots' because of the musky odor they exude from four glands located on the underside of the carapacial margins (Logier 1939). Due to their defensive actions when handled, and small cross-shaped plastron, Eastern Musk Turtles are often mistaken for juvenile Snapping Turtles (*Chelydra serpentina*). Adult and older juvenile *Chelydra serpentina*, however, have long, thick tails with a row of large upright scales. Furthermore, the carapace of *C. serpentina* is wider and flatter than that of Eastern Musk Turtles (Harding 1997).

Genetic Description

The Eastern Musk Turtle has 56 chromosomes: 26 macrochromosomes (14 metacentric, 8 submetacentric, 4 telocentric) and 30 microchromosomes (Stock 1972; Killebrew 1975). The Eastern Musk Turtle is monotypic, no subspecies are recognized. Seidel *et al.* (1981) and Reynolds and Seidel (1983) reported a high level of heterozygosity, but found little difference among populations using morphological characters and electrophoresis. Walker and Avise (1998) reported regional differences in mitochondrial DNA; however, their study was limited to the southeastern United States.

Population Spatial Structure and Variability

As of 2011, no information exists on population spatial structuring and variability for Eastern Musk Turtles in Canada. Several sites may be isolated due to agricultural land conversion and large bodies of open water (e.g., Point Pelee, Long Point), but no studies have quantified the genetic structure of Eastern Musk Turtle populations in Canada.

Designatable Units

As of 2011, there is no information on genetic distinctiveness or structure across the Canadian range of the Eastern Musk Turtle. The species is inferred to be a single evolutionary unit.

On the other hand, natural disjunction is evident between substantial portions of the species' geographic range. Movement between southwestern Ontario populations and those further north (central Ontario, eastern Ontario, and Québec) is believed to have been severely limited for an extended period of time (> 25 years). The Eastern Musk Turtle occupies three distinct COSEWIC Terrestrial Amphibians and Reptiles Faunal Provinces (COSEWIC 2011): Carolinian, Great Lakes/ St. Lawrence, and Canadian Shield (Figure 2). Dispersal between populations of Eastern Musk Turtles along the border of two of these faunal provinces, Carolinian and Great Lakes/ St. Lawrence, is possible but unlikely. Movement among Carolinian populations is also unlikely due to wide separation and high habitat conversion in this faunal province (Figure 2). In the absence of genetic data, however, it is unknown whether local adaptations have arisen or if populations found in the Carolinian Faunal Province are evolutionarily distinct. The loss of the few, small Eastern Musk Turtle populations in the Carolinian faunal province would result in an extensive loss to the Eastern Musk Turtle's Canadian distribution.

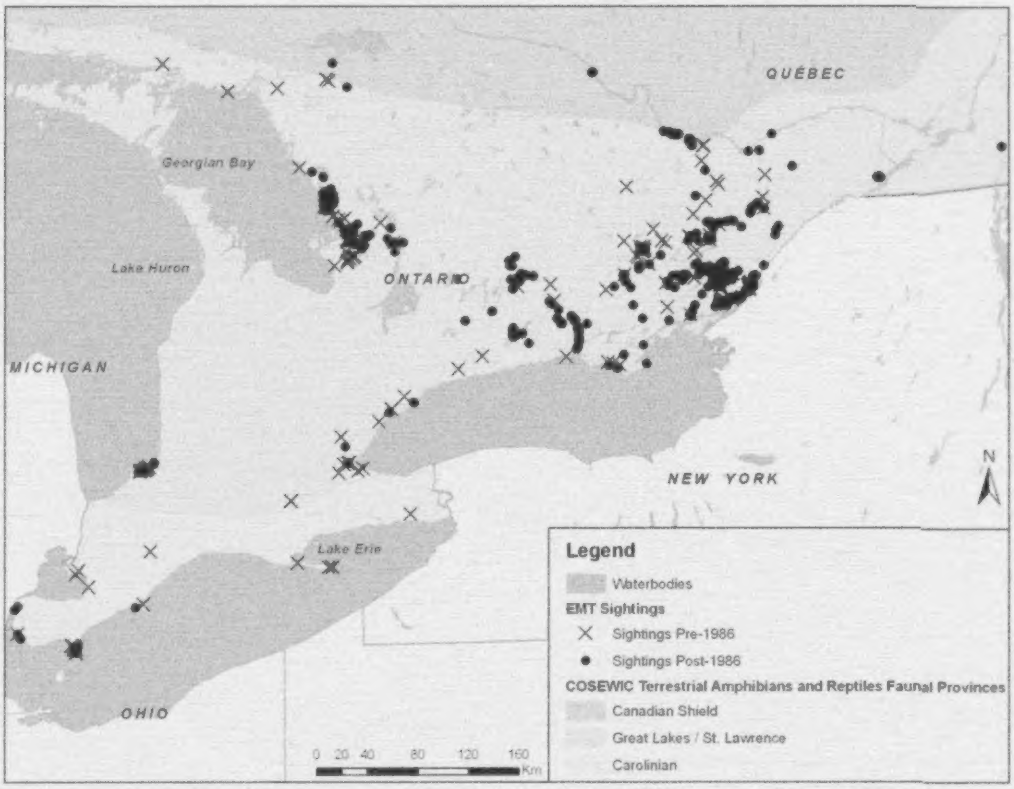
QUÉBEC
Georgian Bay
Lake Huron
ONTARIO
MICHIGAN
NEW YORK
N
Lake Erie
OHIO
0 20 40 80 120 160
Km
Legend
Waterbodies
EMT Sightings
Sightings Pre-1986
Sightings Post-1986
COSEWIC Terrestrial Amphibians and Reptiles Faunal Provinces
Canadian Shield
Great Lakes / St. Lawrence
Carolinian

Figure 2. Eastern Musk Turtle sightings in relation to COSEWIC's Terrestrial Amphibians and Reptiles Faunal Provinces. Map prepared by Catherine Millar, Ottawa, 2012.

Given the lack of genetic evidence on spatial structuring and discreteness across its Canadian range, all populations of Eastern Musk Turtles in Canada are treated in this report as a single designatable unit (DU).

Special Significance

The Eastern Musk Turtle is the only representative of the Kinosternidae family in Canada. Furthermore, the Québec and Ontario populations of Eastern Musk Turtles are at the northern extreme of the species' global range. Currently, there are nine freshwater turtle species native to Canada, not including the extirpated Pacific Pond Turtle (*Actinemys marmorata*). With the exception of the Eastern Box Turtle (*Terrapene carolina*) (data deficient) and certain Painted Turtle (*Chrysemys picta*) populations (e.g., Western Painted Turtle (*C. p. belli*) - Prairie / Western Boreal - Canadian Shield population), all these freshwater turtle species are designated as Species at Risk in Canada (COSEWIC 2010a).

No ATK was available for this species.

DISTRIBUTION

Global Range

The Eastern Musk Turtle is restricted to eastern North America. The species ranges from Florida, north to Ontario and Québec, and west to Wisconsin and Central Texas (Figure 3). In Canada, the Eastern Musk Turtle is found in southern Ontario (southwestern, central, and eastern Ontario), the southeastern edge of northeastern Ontario (Sudbury District) and the extreme southwestern edge of Québec (Figure 3). In the United States, this species is present in the District of Columbia and 33 states: Alabama, Arkansas, Connecticut, Delaware, Florida, Georgia, Illinois, Indiana, Iowa, Kansas, Kentucky, Louisiana, Maine, Maryland, Massachusetts, Michigan, Mississippi, Missouri, New Hampshire, New Jersey, New York, North Carolina, Ohio, Oklahoma, Pennsylvania, Rhode Island, South Carolina, Tennessee, Texas, Vermont, Virginia, West Virginia, and Wisconsin.

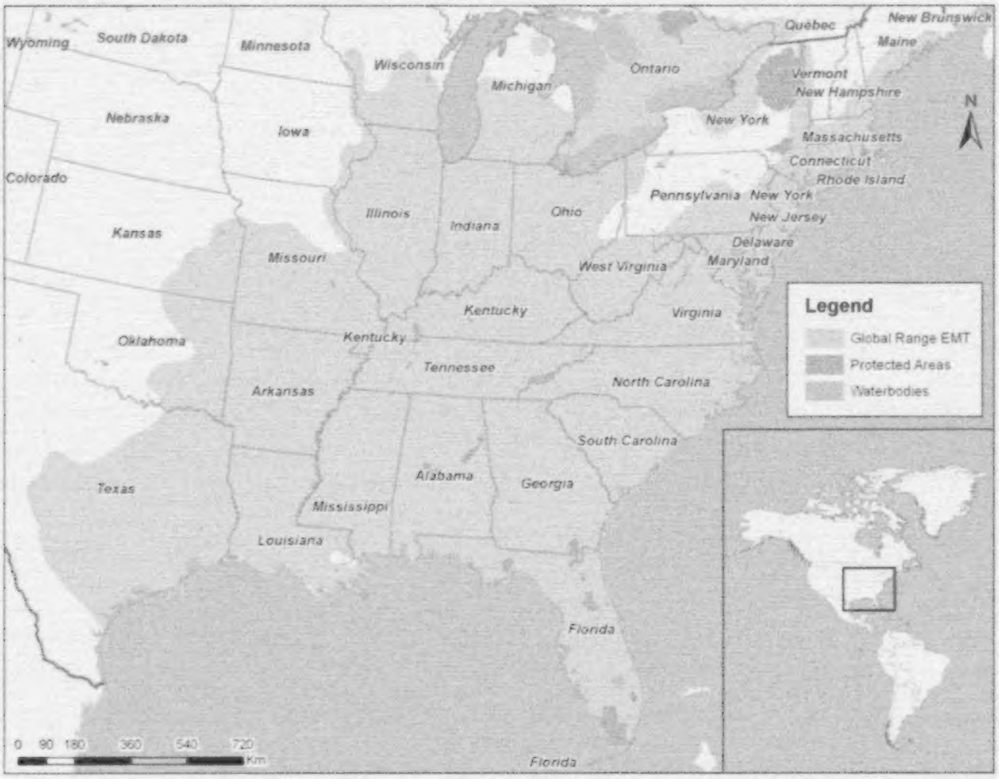
Wyoming
South Dakota
Minnesota
Wisconsin
Michigan
Ontario
Quebec
New Brunswick
Maine
Vermont
New Hampshire
N
Nebraska
Iowa
New York
Massachusetts
Connecticut
Rhode Island
Colorado
Pennsylvania
New York
New Jersey
Illinois
Indiana
Ohio
Kansas
Missouri
Delaware
Maryland
West Virginia
Kentucky
Virginia
Legend
Global Range EMT
Protected Areas
Waterbodies
Oklahoma
Kentucky
Tennessee
North Carolina
Arkansas
South Carolina
Alabama
Georgia
Texas
Mississippi
Louisiana
Florida
0 90 180 360 540 720
Km
Florida

Figure 3. Global distribution of the Eastern Musk Turtle (EMT), *Sternotherus odoratus* (adapted from NatureServe 2010). Map prepared by Catherine Millar, Ottawa, 2012.

Fossil remains of Eastern Musk Turtles dating back to the Pliocene (5.3 million to 2.6 million years before present) have been discovered in Kansas (Holman 1972, 1981). Fossils and fossilized remains from Eastern Musk Turtles, dating back to the Pleistocene (2.6 million years to 12000 years before present) have also been found in Oklahoma (Preston 1979), Florida (Weigel 1962), Indiana (Holman and Richards 1993), Kansas (Preston 1979; Holman 1987), South Carolina (Bentley and Knight 1998), and Texas (Holman 1969; Preston 1979). Holocene (12000 years before present to present day) sub-fossils have been found in Indiana (Swineheart and Holman 1999) and Michigan (Holman 1990).

Canadian Range

Approximately 5% of the global range of the Eastern Musk Turtle extends into Canada (NatureServe 2010). In Canada, the Eastern Musk Turtle is found mostly along the southern edge of the Canadian Shield (Figure 2). It has been reported at various sites close to the shores of Lakes Huron, Erie, and Ontario (Figures 2, 4). The northernmost sightings were recorded in the Frood Lake/ Lake Huron (Whitefish Falls) area, in the Sudbury Census Division, Ontario, and in the township of Hardy, in the Parry Sound Census Division, Ontario (46°N) (Figures 2, 4). Approximately 98% of the Canadian range of this species is in Ontario and 2% in Québec.

The extent of occurrence (EO) was calculated by creating a minimum convex polygon encompassing all historical and recent Eastern Musk Turtle sightings in Canada. This polygon was then clipped (restricted) within Canada's extent of jurisdiction. This produced an EO estimate of 170 617 km^2 (Appendix 1). When open water in the Great Lakes, further than 500 m from shore, was removed from the aforementioned polygon, the EO estimate was reduced to 132 205 km^2 (Millar pers. obs. 2011). The index of area of occupancy (IAO) was determined by summing the area under 352 2 km x 2 km grids overlain on both historical and recent Eastern Musk Turtle sightings. This IAO was 1408 km^2 (Appendix 2).

Between 1858 and 2011, occurrences of Eastern Musk Turtle were documented in 29 Ontario Census Divisions and 3 Québec Census Divisions; since 1986, there have been no sightings in 8 of the Ontario Census Divisions (Table 1, Figure 4). Combined with survey efforts yielding no sightings and high habitat conversion rates in surrounding areas, these findings suggest that certain populations of this species may be extirpated, most noticeably populations in the Golden Horseshoe (i.e., Hamilton) and southwestern Ontario (i.e., Thames River, Rondeau Bay, Long Point). Currently, Eastern Musk Turtles are confined primarily to the southern tip of southwestern Ontario (e.g., Point Pelee National Park, Malden, Port Franks), in select areas in central Ontario (e.g., West Lake, Otonabee River, Trent River), and along the southern edge of the Canadian Shield (e.g., Georgian Bay, Ottawa River, Mississippi River, Frontenac Arch; Figures 2, 4, 5).

Table 1. List of census divisions (2006) where Eastern Musk Turtle sightings have been recorded. The last year in which the species was recorded, the number of sightings per census division (CD), and the number of populations per CD are also included. Census divisions where Eastern Musk Turtle sightings have only recently been recorded, following the last COSEWIC status report (Edmonds 2002), are identified by ND in the CD column. Census divisions where Eastern Musk Turtle sightings have not been reported since 1986 are shaded in grey and CDs with at least one newly identified population are indicated by ^{NP} in the # of populations column.

Province	Census Division	Last Sighting	# Sightings	# of Populations	Notes
Ontario	Brant	1980	2-5	1	
	Durham	1975	2-5	2	
	Essex	2009	25-50	4NP	
	Frontenac	2011	100-1000	13 NP	One population extends into Leeds and Grenville.
	Haldimand-Norfolk	1985	2-5	2	
	Halton	2010	2-5	2 NP	
	Hamilton	2001	5-15	4	
	Hastings	2008	25-50	4 NP	Two populations extend into Northumberland.
	Kawartha Lakes	2005	2-5	2 NP	
	Kent	2003	2-5	2	
	Lambton	2010	50-100	2	
	Lanark	2011	50-100	10 NP	One population extends into Ottawa-Carleton and Leeds & Grenville; A second population extends into Leeds & Grenville only.
	Leeds & Grenville	2011	100-1000	12 NP	One population extends into Ottawa-Carleton and Lanark; A second population extends into Lanark only.
	Lennox & Addington	2006	5-15	7 NP	
	Toronto	2003	5-15	4 NP	3 out of 4 locations have had no reported sightings since 1986.
	Middlesex	pre-1984	1	1	
	Muskoka	2010	50-100	6	One population extends into Simcoe.
	Niagara	1979	1	1	
	Northumberland	2010	25-50	5 NP	Two populations extend into Hastings; One population extends into Peterborough.
	Ottawa	2007	5-15	5 NP	3 out of 5 locations have had no reported sightings since1986.
	Parry Sound	2009	>1000	6 NP	Site of radio-telemetry study (all radio-telemetry locations were recorded and sent to the NHIC - more than one sighting per turtle).
	Peel	1969	1	1	
	Peterborough	2009	50-100	8 NP	One population extends into Northumberland.
	Prescott & RussellND	2006	1	1 NP	
	Prince Edward	1990	5-15	4	
	Renfrew	2007	5-15	3 NP	One population extends into Pontiac.
	Simcoe;	1984	5-15	2	One population extends into Muskoka.
	Stormont, Dundas & GlengarryND	2010	25-50	1 NP	
	Sudbury	1983	2-5	2	
Québec	Les Collines-de-l'Outaouais	2007	1	1 NP	
	Gatineau	1989	1	1	
	Le Haut-Richelieu	2009	1	1 NP	
	Pontiac	2011	25-50	3 NP	

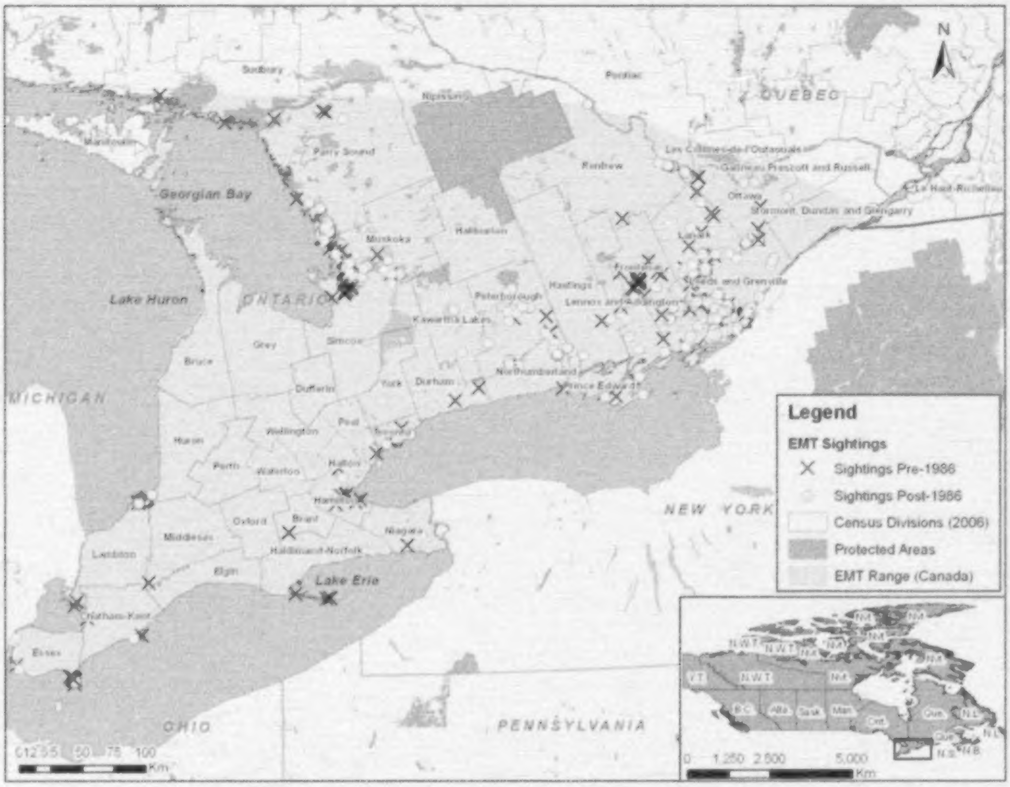
N
QUEBEC
Sudbury
Nipissing
Pontiac
Parry Sound
Manitoulin
Georgian Bay
Renfrew
Les Collines-de-l'Outaouais
Gatineau
Prescott and Russell
Le Haut-Richelieu
Ottawa
Stormont, Dundas and Glengarry
Muskoka
Haliburton
Lanark
Frontenac
Leeds and Grenville
Hastings
Peterborough
Lennox and Addington
Lake Huron
ONTARIO
Kawartha Lakes
Grey
Simcoe
Bruce
Dufferin
York
Durham
Northumberland
Prince Edward
MICHIGAN
Huron
Wellington
Peel
Toronto
Perth
Waterloo
Halton
Hamilton
Oxford
Brant
Middlesex
Niagara
Lambton
Haldimand-Norfolk
Elgin
Lake Erie
Chatham-Kent
Essex
OHIO
PENNSYLVANIA
NEW YORK
0 12.5 25 50 75 100
Km
Legend
EMT Sightings
Sightings Pre-1986
Sightings Post-1986
Census Divisions (2006)
Protected Areas
EMT Range (Canada)
N.W.T.
Nu
Y.T.
B.C.
Alta
Sask
Man
Ont.
Que.
N.L.
N.S.
N.B.
0 1,250 2,500 5,000
Km

Figure 4. Eastern Musk Turtle, range and sightings in Canada. Map prepared by Catherine Millar, Ottawa, 2012.

The only specimens captured or observed in Québec originate from five areas along the north shoreline of the Ottawa River and one area along the shoreline of the Bernier River, a tributary to the Richelieu River: (1) McLaurin Bay, Gatineau (Chabot and St-Hilaire 1991); (2) Deschênes Lake, Les Collines-de-l'Outaouais; (3) in the Knox Landing sector of Bristol, Pontiac (Belleau 2008; Toussaint pers. comm. 2011); (4) in the Clarendon sector of Pontiac (e.g., Portage-du-Fort, Wickens Bay, Sand Bay) (Desrosiers and Giguère 2008; Toussaint and Caron 2012); and (5) Bernier River, Saint-Jean-sur-Richelieu, Le Haut-Richelieu (AARQ 2011) (Figure 5). Although Le Haut-Richelieu is within the same COSEWIC Amphibian and Reptile Faunal Province as the other Québec Eastern Musk Turtle 'locations', the validity of this particular sighting is doubted by local experts (Giguère and Dubois pers. comm. 2012). For this reason, the Bernier River sighting is presented in the figures but is not included in the IAO and EO calculations.

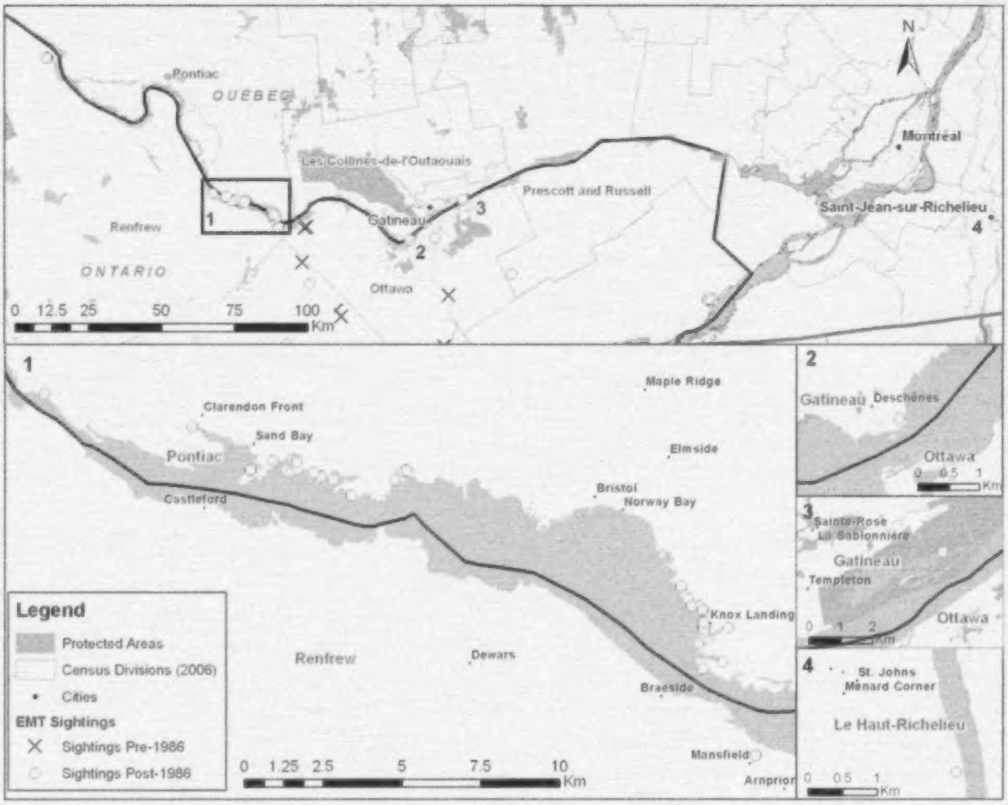
N
Pontiac
QUEBEC
Les Collines-de-l'Outaouais
Prescott and Russell
Montréal
Saint-Jean-sur-Richelieu
Gatineau
Renfrew
ONTARIO
Ottawa
1
2
3
4
0 12.5 25 50 75 100 Km
1
Clarendon Front
Sand Bay
Pontiac
Castleford
Maple Ridge
Elmside
Bristol
Norway Bay
Knox Landing
Renfrew
Dewars
Braeside
Mansfield
Arnprior
0 1.25 2.5 5 7.5 10 Km
Legend
Protected Areas
Census Divisions (2006)
Cities
EMT Sightings
Sightings Pre-1986
Sightings Post-1986
2
Gatineau
Deschênes
Ottawa
0 0.5 1 Km
3
Sainte-Rose
La Sablonnière
Gatineau
Templeton
Ottawa
0 1 2 Km
4
St. Johns
Ménard Corner
Le Haut-Richelieu
0 0.5 1 Km

Figure 5. Eastern Musk Turtle sightings in Québec. Map prepared by Catherine Millar, Ottawa, 2012.

Search Effort

Eastern Musk Turtle sighting records, dating back to the 1850s, are available from the Ontario Herpetofaunal Summary Atlas (Natural Heritage Information Centre), the Canadian Museum of Nature, Ontario's Reptile and Amphibian Atlas (Ontario Nature), and the Atlas of Amphibians and Reptiles of Québec (St. Lawrence Valley Natural History Society and Ministère des Ressources naturelles et de la Faune), in existence since 1988. Over two thirds of reported Eastern Musk Turtle sightings originate from surveys and studies specifically directed to turtles. Most of these surveys are detailed below. The remaining third derive from nonsystematic searches and observations. These combined records give a reasonable index of the species' range in Canada.

Eastern Musk Turtles have been observed in several provincial parks in Eastern Ontario: Bon Echo, Charleston Lake, Frontenac, Kawartha Highlands, Murphy's Point, Puzzle Lake, Presqu'ile, and Sandbanks (Brdar pers. comm. 2011). In Frontenac Provincial Park and Charleston Lake Provincial Park, targeted Eastern Musk Turtle surveys were conducted in 2005. A total of 22 individuals were observed in Frontenac Provincial Park over a week using the spotlight method after nightfall (Brdar pers. comm. 2011). Two individuals were observed in Charleston Lake Provincial Park after two hours of searching using the spotlight method and 10 individuals were caught and radio-tracked in this park from September 2007 to September 2008 (Brdar pers. comm. 2011).

Eastern Musk Turtle surveys have been conducted along the Rideau Canal National Historic Site (RCNHS) from 2006 to 2011. Turtle surveys were carried out from May to August using hoop nets, basking traps and active searches. A total of 45 Eastern Musk Turtles were caught at various sites along the RCNHS and the corresponding locations can be found in Appendix 1 (Mayberry pers. comm. 2012). Site surveys lasted from 3 to 15 days and, in 2007 specifically, 47 sites were trapped over 48 days (using mainly hoop nets) along a 92.7 km stretch of the RCNHS. A targeted survey of the Thousand Islands Watershed in 2009 and 2010 (July – August) detected Eastern Musk Turtles at 41 of the 66 (62 %) randomly selected sites (Quesnelle pers. comm. 2011). Eastern Musk Turtles were found throughout the St. Lawrence River and every major natural waterbody (e.g., Gananoque Lake, South Lake, Charleston Lake) and watercourse (e.g., Lyndhurst Creek, Gananoque River, Rideau Canal) in the area (Quesnelle pers. comm. 2011). Sites were actively searched for Eastern Musk Turtles for a maximum of eight person-hours each. These targeted surveys did not detect Eastern Musk Turtles in human-made impoundments or reservoirs (e.g., Centre Lake, Wiltse Lake, Lees Pond, Mac Johnson), despite the presence of suitable habitat (Quesnelle pers. comm. 2011). Some of these reservoirs are connected by major watercourses whereas some are on a dam-system. Additionally, 4 years of mark-recapture data are available for Eastern Musk Turtles around Grenadier Island, in the St. Lawrence River (Carrière 2007; Carrière and Blouin-Demers 2007; Millar 2008; Picard *et al.* 2011). A total of 200 Eastern Musk Turtles were captured from 2005-2008 around Grenadier Island.

In 2008, the Trent and Otonabee rivers were the subject of a mark-recapture study of Eastern Musk Turtles. From May to August, six Eastern Musk Turtles were found in the Trent River and 71 were found in the Otonabee River (Bennett pers. comm. 2011). In 2009, a Species at Risk inventory (30 days of visual surveys) was performed in the coastal wetland system of Presqu'ile Bay and no Eastern Musk Turtles were found (Savanta Inc. 2010).

In 2007, a Species at Risk (SAR) study of four Department of National Defence (DND) properties in Ontario (8 Wing/CFB Trenton, Point Petre Transmitter Site; Canadian Forces Detachment Mountain View; and Carrying Place Receiver Site) did not observe any Eastern Musk Turtles (Trow Associates Inc. 2007). Investigators were actively searching for Eastern Musk Turtles, among other specifically targeted SAR species, but did not employ hoop nets.

In 2010, Lake Opinicon was extensively sampled as part of a freshwater turtle bycatch study (Larocque *et al.* 2012a, 2012b). In spring and summer 2010, 393 hoop nets were placed and retrieved and 161 Eastern Musk Turtles were caught overall (Larocque pers. comm. 2011; Larocque *et al.* 2012b). Eastern Musk Turtles were not marked in this study and undoubtedly many captures were recaptures.

The Ottawa River and associated waterways have been surveyed on several occasions since the last COSEWIC report in 2002. In 2005, a preliminary 18-day Eastern Musk Turtle survey in the Knox Landing sector of Bristol using hoop nets and active searches captured 17 Eastern Musk Turtles; catch per day-trap was 0.06 when actively searching and 0.27 when using a hoop net (Belleau 2010). In 2006, a 4-month mark-recapture study in the same area resulted in identification of 109 Eastern Musk Turtles (Belleau 2008). In 2007, a 12-day active search (326 person hours) in Wickens Bay, 15 km upstream of the Bristol site, revealed six *S. odoratus* (Desrosiers and Giguère 2008). A multi-species survey in 2010 along the Ottawa River, from Portage-du-Fort to Norway Bay (Knox Landing), revealed one Eastern Musk Turtle along the Québec shoreline at Reid Island in addition to the previously identified population in the Knox Landing section of Bristol (Toussaint pers. comm. 2011). In 2011, a targeted Eastern Musk Turtle survey (41 hours of active searches and 291 trap-days) along 18 km of the Ottawa River, primarily between Indian Bay and Norway Bay, yielded 23 Eastern Musk Turtles (Toussaint and Caron 2012). Eastern Musk Turtles were observed in Wickens Bay, Heath's Bay, Birch's Stream, Boom Island, Armstrong's Bay, Armstrong Island's Bay, and John's Bay (Toussaint and Caron 2012). In 2009 and 2010, 1-day surveys were carried out in the Deschênes Rapids along the Ottawa River, Aylmer, Québec, and no Eastern Musk Turtles were found (Dubois pers. comm. 2011). A 5-day turtle survey in 2007 (7 July, 13 July, 27 July, 10 August, 20 September) in Shirleys Bay Crown Game Preserve, Ottawa, Ontario, also found no Eastern Musk Turtles (Seburn 2008). This survey was approximately 7.5 km southwest of the Deschêne Rapids and both waterways are connected by Deschênes Lake. In 2007, a targeted Eastern Musk Turtle survey at Canadian Forces Base Petawawa yielded four Eastern Musk Turtles using hoop nets at 18 sites for 20 days (Richard 2011).

In 2005, a turtle survey (110 hours of active searches and 29 trap-nights) in the Lac Saint-François National Wildlife Area and the Akwesasne Reserve did not observe any Eastern Musk Turtles (Giguère 2006).

In 2010, a targeted turtle survey along five transects (active search and 11 hoop nets) in the Raisin River captured 22 Eastern Musk Turtles (Jacobs pers. comm. 2011).

Only three records exist in the Ontario Herpetofaunal Atlas for Eastern Musk Turtles in the Thames River watershed, all were recorded prior to 1984 (Oldham and Weller 2000). The Thames River is situated in a highly developed urban and rural region of Southern Ontario (Cudmore *et al.* 2004). This region supports a large human population and the watershed land base is intensively used for both livestock and crop agriculture. According to the Thames River Watershed Summary Report, Eastern Musk Turtles may be extirpated from this area (The Thames River Ecosystem Recovery Team 2010).

Several sites along the eastern coast of Georgian Bay have been surveyed in recent years. From 1991 to 1997, 575 turtles were caught 931 times during active searches (May-August) around Loon Island, Georgian Bay, during a long-term mark-recapture study (Edmonds 1998). In 2008 and 2009, 327 Eastern Musk Turtles were caught in Massasauga Provincial Park, Georgian Bay, using active searches (Laverty 2010). A timed search (5313 person hours) resulted in a catch per unit effort of 0.028 turtles per hour of active searching.

In 2008 and 2009, Eastern Musk Turtles were surveyed in the Port Franks area and along the Old Ausable Channel, the southeastern coast of Lake Huron (Davy pers. comm. 2011). Three individuals were located in the Old Ausable Channel and 40 in the Port Franks area (Davy pers. comm. 2011). Additionally, single day visual surveys (6-30 person-hours per survey) in the Port Franks area have occurred yearly from 1997 to 2011 (Gillingwater 2005). Each survey resulted in observations ranging from one to 12 Eastern Musk Turtles and all turtles were found in three relatively small water bodies in the Port Franks area (Gillingwater unpub. data). During turtle basking surveys at former Camp Ipperwash, three Eastern Musk Turtle observations were made in 2010 and a fourth in 2011 (Dean Nernberg pers. comm. 2012). Surveys of nearby wetlands, however, have resulted in no additional Eastern Musk Turtle observations, and there is a scarcity of quality wetland sites available beyond Pinery Provincial Park, Port Franks and Ipperwash areas (Gillingwater unpub. data). Additionally, Common Reed (*Phragmites australis australis* is quickly changing shoreline conditions for many water bodies along the Great Lakes, including sites in the Port Franks area (Gillingwater unpub. data).

Only a few musk turtles have been reported from the Long Point area and Rondeau Provincial Park, along the north shore of Lake Erie. The Eastern Musk Turtle was first reported in Long Point Provincial Park in 1978 and in Rondeau Bay in 1976. Dedicated surveys from 1996 to 1999 and from 2003 to 2004 in lake marsh and interior pond habitat at the tip of Long Point (including the Long Point National Wildlife Area, OMNR property, and Ministry of Transportation property) revealed only a single dead specimen along the north shore of the point in 2003, despite hundreds of hours of surveying (Gillingwater and Piraino 2004, 2005). Dedicated turtle surveys in the Big Creek National Wildlife Area (2003 to 2012), the Crown Marsh (2009), and the shoreline of Long Point Bay along the Long Point Causeway (2003 to 2011) resulted in no observations of Eastern Musk Turtles (Gillingwater unpub. data). Sporadic surveys from 1996 to 1999 and dedicated surveys in 2000 and 2001 at Rondeau Provincial Park

(Rondeau Bay and wetlands adjacent to Rondeau Bay) resulted in no observations of Eastern Musk Turtles, despite hundreds of person-hours (Gillingwater and Brooks 2001). There is only one recent report (2003) of an Eastern Musk Turtle in the Rondeau Bay area; a broken carapace was found in McGeachy Pond Conservation Area. Surveys at both the tip of Long Point and Rondeau Provincial Park included nesting surveys, wading in water, snorkeling and night spotlight surveys. Surveys in the Big Creek National Wildlife Area and Long Point Bay shoreline included wading in water along the shoreline.

Eastern Musk Turtles were first observed in Point Pelee National Park in 1913 by C.L. Patch during a 3-month herpetofaunal survey (Patch 1919). Since then, several herpetofaunal surveys have been performed in Point Pelee National Park, including cursory visual surveys (Logier 1925; Harris and Stirret 1951; Bouckhout 1967; Cook 1967, 1974; Dutcher 1967; Roy 1967; Wyett 1967; Ross 1971; Kraus 1991) and mark-recapture studies (Bevan 1972; Rivard and Smith 1973; Browne 2003). The most recent turtle survey in Point Pelee National Park (2001-2002) found 24 individual Eastern Musk Turtles (Browne 2003). No Eastern Musk Turtles were found in nearby Hillman Marsh in 2001 (Browne 2003).

HABITAT

Habitat Requirements

The Eastern Musk Turtle is a highly aquatic species usually inhabiting littoral zones and shallow waterways (Ford and Moll 2004) like rivers, lakes, bays, streams, ponds, canals, and swamps with slow current and soft bottom (Street 1914; Cahn 1937; Finneran 1948; Lindsay 1965; Petokas and Gawlik 1982; Cook 1984; Ernst 1986; Chabot and St-Hilaire 1991; Conant and Collins 1998; Edmonds 1998; Belleau 2008). However, they have also been found in gravel-bottomed streams (Mahmoud 1969; Ernst and Lovich 2009). In Canada, Eastern Musk Turtles have been found in lakes, streams, marshes, ponds and rivers (e.g., Lindsay 1965; Brunton 1981; Chabot and St. Hilaire 1991; Edmonds and Brooks 1996; Browne 2003; Carrière and Blouin-Demers 2007; Belleau 2008; Millar 2008; NHIC unpub. data).

Eastern Musk Turtles are habitat specialists and prefer shallow water (depth < 2 m) with abundant floating and submerged vegetation (Mahmoud 1969; Chabot and St-Hilaire 1991; Edmonds 1998; Carrière 2007; Belleau 2008; Laverty 2010; Picard *et al.* 2011). These habitats are thermally superior to other available habitat and may enable turtles to reach optimal body temperatures during the active season in their cool Canadian range (Picard *et al.* 2011) without having to leave water to bask. Submerged vegetation is an important foraging habitat for Eastern Musk Turtles (Belleau 2008; Picard *et al.* 2011). A strong selection for and use of active Beaver (*Castor canadensis*) lodges and submerged logs have also been reported (Kiviat 1978; Belleau 2008; Ernst and Lovich 2009). No effect of sex on habitat selection has been observed (Belleau 2008). In Point Pelee National Park, Eastern Musk Turtles were most abundant in sites that had low visitor activity, were close to a large waterway (Lake Erie), and had a bottom of mud and sand (Browne 2003; Gillingwater pers. comm. 2012). Eastern Musk Turtles are not tolerant of brackish water (Dunson 1986). Finally, individuals are most often found close to shore (mean distance to shore = 5 ± 0.3 m) (Carrière 2007), in shallow (< 2 m depth) water (Edmonds 1998), and usually do not venture onto land except to nest or to access adjacent wetlands (Ernst and Lovich 2009; Edmonds 1998).

In a Parry Sound, Ontario, population, Eastern Musk Turtles associated with a variety of vegetation, including grasses (Poaceae), sedges (Cyperaceae), rushes (Juncaceae), cattails (*Typha sp.*), pipewort (*Eriocaulon sp.*), water shield (*Brasenia sp.*), hornwort (*Ceratophyllum sp.*), Elodea (*Elodea sp.*), Bullhead Lily (*Nuphar variegatum*), Fragrant Water Lily (*Nymphaea odorata*), Pickerel Weed (*Pontederia cordata*), pondweed (*Potamogeton sp.*), arrowhead (*Sagittaria sp.*), bladderwort (*Utricularia sp.*), and water celery (*Vallisneria sp.*) (Edmonds 1998). In St. Lawrence Islands National Park, Ontario, Eastern Musk Turtles were found in association with Bullhead Lily, Fragrant Water Lily, duckweed (Lemnaceae), cattails, and other macrophytes that served as surface cover (Picard *et al.* 2011). In Québec, Eastern Musk Turtles were found in association with Canadian Waterweed (*Elodea canadensis)*, Common Frogbit (*Hydrocharis morsus-ranae)*, Bulltongue Arrowhead (*Sagittaria latifolia)*, Fragrant Water Lily, and Ribbonleaf Pondweed (*Potamogeton epihydrus)* (Chabot and St. Hilaire 1991).

Nesting habitat is variable. Most nests are shallow excavations (up to a maximum depth of 10 cm) in decaying vegetable matter, rotting wood (such as under stumps or fallen logs), in sand, among sparse shoreline grasses, in sawdust piles, or in the walls of Muskrat (*Ondatra zibethicus*) or Beaver lodges (Cagle 1937; Cahn 1937; Edgren 1942; Kiviat 1978; Ernst 1986; Ernst and Lovich 2009). Eastern Musk Turtles on the Precambrian Shield also nest in shallow gravel or soil-filled rock crevices close to the shoreline (Lindsay 1965; Edmonds 1998). Nests were on rock faces exposed to direct sunlight. High thermal quality nesting sites may be limited in central and eastern Ontario and southwestern Québec, the northern extreme of this species' global range, and direct sunlight is necessary to provide sufficient warmth to complete incubation (Bobyn and Brooks 1994). Ernst (1986) noted that nest sites are generally 3 to 11 m from shore and nesting was a nighttime activity. Cahn (1937) observed that eggs left uncovered did not hatch.

Generally, Eastern Musk Turtles hibernate underwater buried under approximately 30 cm of mud (Ernst and Lovich 2009). They may also hibernate in burrows, Beaver and Muskrat lodges, and under stumps or rocks near water (Ernst and Lovich 2009). One hibernaculum in Mallorytown, Ontario, had a water depth of nearly 3 m (Carrière 2007). Eastern Musk Turtles begin to burrow when water temperatures fall below 10°C and, sometimes, individuals will congregate in large numbers at suitable hibernacula (e.g., 450 individuals; Thomas and Trautman 1937).

Habitat Trends

Suitable Eastern Musk Turtle habitat appears abundant across central and eastern Ontario, especially in the Canadian Shield Region. Urbanization, however, continues to encroach on many waterways and wetlands in Ontario, primarily close to Lake Ontario and Lake Erie, where some Eastern Musk Turtle populations are located. Between 1971 and 2001, Ontario's urbanized land coverage grew by almost 80% (Pond 2009). Furthermore, 72.3% of pre-settlement (c. 1800) wetlands in southern Ontario were converted to other uses by 2002 (Ducks Unlimited Canada 2010).

The highest pre-settlement wetland conversion rates were observed in southwestern Ontario (Essex, Kent, Lambton, Middlesex, and Perth), parts of eastern Ontario (Prescott and Russell), and in Brant, Niagara, and Toronto. In these areas, over 85% of the original wetlands were converted to other uses (Ducks Unlimited Canada 2010). Prior to 1986, Eastern Musk Turtles were reported in 8 of the 9 census divisions listed above. Since then, however, Eastern Musk Turtles have not been reported in three of these eight historical census divisions (Middlesex, Brant, Niagara), in two of the four historical Toronto locations (Don River and Silverthorn), in one of the two Chatham-Kent locations (Lake St. Clair), and in one of the two historical Lambton locations (Johnston Bay) (NHIC upubl. data) (Table 1, Figure 4). Lack of opportunistic occurrence data alone cannot be used to conclude that these populations have been extirpated as not all historical sites have been surveyed in recent years. The habitat available to turtles in these historical census divisions, however, has decreased considerably. In Peel and Toronto, over 50% of converted pre-settlement wetlands were converted to built-up impervious infrastructure (e.g., roads, buildings, and parking lots). The last recorded sighting for Eastern Musk Turtles in Peel was in 1969 (Table 1).

In addition to land conversion, many remaining wetlands are degraded by human activities. Forms of habitat deterioration include: water pollution, bank erosion, riparian vegetation loss, habitat fragmentation, infilling, sedimentation, siltation, water extraction, and altered wetland hydrology. Shoreline development for cottages and recreational activity is destroying suitable habitat in areas occupied by Eastern Musk Turtles on the Precambrian Shield. Habitat deterioration can be particularly pervasive near urban and recreation centres (e.g., Thames River; The Thames River Recovery Team 2010). Also, road networks have considerably expanded over the last century. The major roads of southern Ontario increased from 7,133 km in 1935 to 23,806 km in 1965, and to 35,637 km in 1995 (Fenech *et al.* 2000). The effects of roads range from road mortality, toxic run-off, sedimentation, increased predation, altered drainage patterns, increased habitat invasion by exotic species, and the loss of 'interior' habitat conditions (Forman and Deblinger 2000; Beaudry *et al.* 2008).

The extent to which animal populations in habitat fragments are isolated from those in nearby habitats varies greatly in relation to land use and the biology of the species. The IUCN considers a taxon as severely fragmented if > 50% of its total area of occupancy (AOO) is in habitat patches smaller than required to support a viable population (based on estimates of population density and ecology of the taxon) and separated from other patches by a large distance (based on dispersal ability of the taxon) (IUCN 2001). To estimate the degree of habitat fragmentation Eastern Musk Turtles are currently experiencing across their Canadian range, index of area of occupancy (IAO) (all years) was used as a standardized substitute for AOO and a large distance was defined as a distance greater than 10 km by water and 2 km by land, adapted from the Eastern Musk Turtle separation barriers proposed by NatureServe (2010). Unfortunately, no information is currently available on minimum habitat patch size required to support viable Eastern Musk Turtle populations. Thus, the estimates presented below may overestimate fragmentation as some IAO patches (adjacent IAO polygons make up one IAO patch) may be large enough to support a viable population. However, irrespective of IAO patch size, only a fraction of the habitat found within the IAO patches may represent suitable habitat for Eastern Musk Turtles. To obtain fragmentation estimates, the number of IAO patches separated by a large distance was divided by the total number of IAO patches. Gaps between IAO patches may not reflect true distances between habitat patches but rather gaps in our knowledge of the distribution of the species.

Overall, the Canadian population of Eastern Musk Turtles is not severely fragmented as only 38% of IAO patches are isolated. At the regional level, however, fragmentation can be considered severe in southwestern Ontario (69%) and the Golden Horseshoe (75%) because over 50% of IAO patches in these areas are separated by large distances across highly altered landscapes (urban, agricultural, highways, etc.) (IUCN 2001). Indeed, essentially the entire area south of a line from southern Georgian Bay to Prince Edward County likely qualifies as severely fragmented (Figures 2, 3). Although all IAO patches in northcentral Ontario (Sudbury area, Ottawa River) are separated by large distances, the lack of targeted survey efforts and the abundance of suitable Eastern Musk Turtle habitat in this region prevent drawing strong conclusions on fragmentation. In eastern and central Ontario, habitat fragmentation is still apparent but not severe: only 31% and 28% of IAO patches are isolated.

When these data are examined using the COSEWIC Amphibian and Reptile Faunal Provinces, Eastern Musk Turtle populations are severely fragmented (> 50% of continuous IAO patches are separated by large distances) in the entire Carolinian Faunal Province and the southern half of the Great Lakes St. Lawrence Faunal Province (Figure 2). For fragmented populations, dispersal is the ‘key to survival’ (Opdam 1990). The reduced ability of animals to move through the landscape has a number of major consequences; it limits their capacity to supplement declining populations, to re-colonize habitats where extinctions have occurred, or to colonize newly suitable habitats (Opdam 1990).

BIOLOGY

The biology of Eastern Musk Turtles has been studied by several researchers throughout the species' range. Ernst and Lovich (2009) provide a comprehensive review of the scientific literature pertaining to Eastern Musk Turtles. The literature available for Canadian populations of Eastern Musk Turtles has mushroomed since the last status report (Edmonds 2002). Several studies involving Canadian populations of Eastern Musk Turtles have been completed (Edmonds 1998; Browne 2003; Carrière 2007; Carrière and Blouin-Demers 2007; Belleau 2008; Millar 2008; Laverty 2010; Picard *et al.* 2011; Larocque *et al.* 2012a, 2012b) and others are currently underway (Quesnelle pers. comm. 2011; Bennett pers. comm. 2011). The majority of the biological information on Eastern Musk Turtles presented below comes from these sources.

Life Cycle and Reproduction

Male Eastern Musk Turtles mature at a smaller size than females (Tinkle 1961; Mahmoud 1967; McPherson and Marion 1981a, b; Mitchell 1988) and southern Eastern Musk Turtles mature faster than those in the north. In Ontario, the estimated mean carapace length at maturity was 63.6 mm (5-6 years) for males and 80.7 mm (8-9 years) for females (Edmonds 1998). In Michigan, males are reported to mature at mean carapace lengths of 60-70 mm (3-4 years) and females at carapace lengths of 80 mm (3-7 or 9-11 years) (Risley 1933; Tinkle 1961).

In northern populations of *S. odoratus*, spermatozoa are present in the testes from September to May, and breeding may occur in either fall or spring (Risley 1938). Plasma testosterone and follicle-stimulating hormone (FSH) levels peak from August to October and are thought to play an important role in the onset of fall mating behaviour (McPherson *et al.* 1982; Mendonça and Licht 1986). Decreasing day length is the key environmental stimulus for male sexual activity; however, environmental temperatures still play a role (Mendonça 1987a). Overall, longer days and lower environmental temperatures inhibit mating (Mendonça 1987a).

In Michigan, the female cycle begins in mid- to late June after the last eggs of the year have been ovulated (Edgren 1960; McPherson and Marion 1981a; McPherson *et al.* 1982; Mitchell 1985, 1988). Vitellogenesis begins in late July, causing follicular enlargement, and continues until December (McPherson *et al.* 1982; Mitchell 1985). No further increases occur during winter hibernation (McPherson *et al.* 1982; Mitchell 1985). In spring, additional yolk may be added until the ova reach maximum size just prior to ovulation, which begins in April or May (McPherson and Marion 1981a). High estrogen levels are associated with vitellogenic periods during fall and spring into early summer (McPherson *et al.* 1982). Temperature appears to be the predominant environmental cue affecting follicular growth in Eastern Musk Turtles, whereas photoperiod does not appear significant (Mendonça 1987b). Follicular development is terminated by high environmental temperatures in summer and then reinitiated by reduced temperatures in fall (Mendonça 1987b).

Peak mating times for Eastern Musk Turtles are in spring (April – May) and fall (September – October) when turtles are congregated at hibernation sites (Risley 1933; McPherson and Marion 1981b; Ernst 1986; Mendonça 1987b). In Québec, copulations have been observed in fall only (September) (Saumure 2009). Although courtship and mating behaviour have been described in detail (Mahmoud 1967), the mating system of this species (e.g., polygynous, random, etc.) is unknown. Females can store viable sperm from a fall mating through the winter (Gist and Jones 1989; Gist and Congdon 1998), and there is an account of a female copulating with two different males during the same breeding season (Ernst 1986). Thus, multiple paternity is possible for individual clutches of eggs.

The eggs are elliptical, with a thick, white, brittle shell that appears slightly glazed when dry. Egg size seems to decrease with increasing latitude; eggs are 18.2 mm to 31.0 mm long, 12.3 mm to 18.2 mm wide, and weigh 1.5 g to 4.6 g (Ernst and Lovich 2009). Clutch frequency varies with latitude; southern females lay two to four clutches per year and northern females lay one or fewer clutches per year (Risley 1933; Tinkle 1961; Gibbons 1970; McPherson and Marion 1983; Edmonds 1998). Clutch size increases with body size (Gibbons 1970; Mitchell 1985; Ernst 1986) and can range from 2 to 13 eggs (Tucker and Lamer 2005). Typically, a single clutch is composed of 3 to 7 eggs (Tinkle 1961; Graham and Forsberg 1986; Ewert 2005; Tucker and Lamer 2005). In Canada, Eastern Musk Turtles have been observed laying eggs as early as June 6th and as late as July 23rd (Lindsay 1965; Edmonds 1998). Incubation ranges from 65 to 86 days and hatchlings emerge in August and September (Ernst and Lovich 2009).

Often, more than one female will nest in the same place (Cagle 1937; Edgren 1942) and females may exhibit year-to-year nesting site fidelity. In Georgian Bay, 7 of 10 radio-tracked females inhabiting Twelve Mile Bay nested along the same shoreline of a single 2.5-ha bay (Edmonds 1998). Two of three gravid females tracked in two consecutive years nested in the same bay in both years (Edmonds and Brooks unpub. data). In the Port Franks area, a single oviposition site measuring 6 m by 4 m was used by at least 13 females from a single pond in 2011. Additionally, a single Beaver lodge in an adjacent water body was used by multiple females for oviposition over multiple years (2007 to 2010) (Gillingwater unpub. data).

There are insufficient data to estimate nesting success, hatchling survival, or recruitment rates for Eastern Musk Turtle populations in Ontario or Québec. In Pennsylvania, only 16 of 104 eggs laid (15.4 %) hatched (Ernst 1986). Recruitment was estimated to be 0.5 turtles per nest (Ernst 1986). Typical freshwater turtle life-history patterns are such that recruitment and early juvenile survivorship are low (Iverson 1991b; Congdon *et al.* 1993). Overwintering in nests has been observed in southern populations (Gibbons and Nelson 1978). In northern populations, however, hatchlings overwintering in nests did not survive winter (Risley 1933).

Eastern Musk Turtles have temperature-dependent sex determination. This means that the incubation temperature of the nest determines the sex of hatchlings. Incubation temperatures at or above 28°C produce nearly all females, between 25°C-28°C produce a mixture of males and females, and below 25°C produce up to 80% males (Vogt *et al.* 1982; Clark *et al.* 1986; Ewert *et al.* 2004). Ewert (1971) also noted an acceleration of embryonic development with increasing latitude; this relationship was independent of incubation temperatures. Faster embryonic development decreases the time spent in the nest, which is essential for northern populations as the active season is much shorter.

Physiology, Behaviour, and Adaptability

In Canada, Eastern Musk Turtles are active from April to early October (Edmonds 1998; Belleau 2008; Millar 2008; Picard *et al.* 2011). This annual activity cycle of around 180 days is similar to that reported for Eastern Musk Turtle populations in Pennsylvania (Ernst 1986; Hulse *et al.* 2001), Michigan (Risley 1933), and Ohio (Conant 1951). Although individuals are active during daylight, often observed basking or crawling along the bottom, Eastern Musk Turtles are chiefly crepuscular (Edmonds 1998; Smith and Iverson 2004; Carrière 2007). In Oklahoma and Pennsylvania, peaks in activity occur from 4:00 to 11:00 and 17:00 to 21:00 h in summer (April to September). From September to April, however, most activity occurs between 10:00 and 16:00 h (Mahmoud 1969; Ernst 1986).

Like most freshwater turtles, Eastern Musk Turtles can tolerate long periods of apnea while submerged. Eastern Musk Turtles accomplish this by slowing down their metabolism and absorbing oxygen directly from water. Eastern Musk Turtles are bimodal breathers (exchange gases with both air and water). Under laboratory conditions, free-diving individuals obtained 26% of their required oxygen directly from the water (Stone *et al.* 1992a). Furthermore, 90% of dives were less than 20 min in duration and only 3% of dives exceeded 50 min (Stone *et al.* 1992b).

Eastern Musk Turtles have a lower anoxia (no oxygen) tolerance than Painted (*Chrysemys picta*) and Snapping (*Chelydra serpentina*) Turtles (Ultsch and Cochran 1994; Jackson *et al.* 2007). Hibernating Eastern Musk Turtles in normoxic (normal oxygen levels) conditions can survive underwater at temperatures of 3°C for at least 150 days (Ultsch and Cochran 1994). Hibernating individuals placed in anoxic (no oxygen) conditions at water temperatures of 3°C survive only 21 days (Ultsch and Cochran 1994). This inability to overwinter in hypoxic/anoxic (low/no oxygen) conditions places limitations on where Eastern Musk Turtles can overwinter in Canada. Like most anoxia-intolerant freshwater turtle species in Canada, Eastern Musk Turtles either live in habitats to which they are adapted for overwintering (e.g., lakes, rivers) or migrate from eutrophic environments during the summer to hibernacula that remain normoxic (normal oxygen levels) during winter (e.g., gravel-bottomed waterways with little to no vegetation), if such hibernacula are within migratory reach (Ultsch 2006; Carrière 2007; Belleau 2008)

Eastern Musk Turtles are ectotherms and, as such, they must obtain heat from their environment. Despite some physiological control of body temperature (Weathers and White 1971; Lucey 1974; Seebacher and Franklin 2005), most ectotherms depend on behavioural thermoregulation to maintain their body temperature within the optimal performance range (Cowles and Bogert 1944; Huey and Kingsolver 1989). Although Eastern Musk Turtles rarely emerge from water to bask, they often bask close to the surface of the water under the cover of lily pads, other floating vegetation, and debris (Edmonds 1998; Carrière 2007; Carrière and Blouin-Demers 2007; Millar 2008; Picard *et al.* 2011). In a study by Picard *et al.* (2011) in Ontario, Eastern Musk Turtles chose habitats that permitted them to maintain body temperatures within the preferred body temperature range 41% of the time when preferred body temperatures were available. The thermal activity range is 10° to 34°C, with a preferred field body temperature of 24°C (Mahmoud 1969). The critical thermal maximum for this species ranges between 39.5°C and 41.9°C (Hutchinson *et al.* 1966; Mahmoud 1969). Out of water, Eastern Musk Turtles are highly susceptible to desiccation and are relatively quick to show signs of distress (Ernst 1968).

Dispersal and Migration

Eastern Musk Turtles emerge from hibernation in early to late April and have been observed until early October in Canada (Edmonds 1998; Belleau 2008; Millar 2008; Picard *et al.* 2011). In St. Lawrence Islands National Park, Ontario, Carrière (2007) observed that all long-distance movements occurred overnight. Dispersal is most likely achieved via aquatic corridors. Populations are thought to be isolated if they are separated by more than 10 km of riverine habitat, 5 km of other aquatic habitat (lakes, marshes, ponds, etc.), and 1 km of land (NatureServe 2010). Furthermore, roads, rugged terrain, salt water and inhospitable land uses limit movement between habitat fragments (NatureServe 2010). Locks and dams can limit aquatic dispersal of freshwater turtles (Bennett *et al.* 2010).

Eastern Musk Turtles often return to their initial site of capture (Williams 1952; Ernst 1986; Mitchell 1988; Holinka *et al.* 2003) and Canadian radio-telemetry studies suggest limited movement (daily mean: 25 to 131 m; daily min: 0.1 m; daily max: 1000 m) (Edmonds 1998; Carrière 2007; Belleau 2008; Laverty 2010) (Table 2). However, individual home range sizes vary considerably within and among sites in Canada (mean: 6.2 to 155.4 ha; min: 0.08 ha; max: 430 ha) although most Canadian estimates are considerably larger than those of more southern populations (Mahmoud 1969; Ernst 1986) (Table 2). Habitat fragmentation (Edmonds 1998; Belleau 2008), decreased habitat productivity at northern latitudes (Harestad and Bunnell 1979), and differential habitat selection for overwintering and residential habitats at northern latitudes (Ultsch 2006) may explain larger home ranges. For example, the exceptionally large home ranges reported by Edmonds (1998) in Georgian Bay occurred as an outcome of scattered habitat patches (i.e., shallow areas around islands widely separated by large expanses of deep water).

Table 2. Daily distance travelled and home range estimates for Eastern Musk Turtle populations in Canada.

Study Site	Sex (All, M, F)	Mean Daily Distance Travelled (m/day)	Min - Max Daily Distance Travelled (m/day)	Mean Home Range Area (ha)	Min - Max Home Range Area (ha)	Home Range Estimate Includes Land (Y, N)	Source
Massasauga Provincial Park, Georgian Bay, ON	All	78.5 ± 6.7	25 - 120	34.6 ± 4.4	11 - 183	N	Laverty 2010
Grenadier Island, St. Lawrence River, ON	All	25.6 ± 1.98		6.2 ± 4.2	0.08 - 35.1	N	Carrière 2007
	All			6.6 ± 1.1	0.6 - 22.1	N	Picard 2008
Otonabee River, ON	All			120.6 ± 103.0	7.6 - 429.5	Y	Bennett pers. comm. 2011
Loon Island, Georgian Bay, ON	All				10.6 - 430.0	Y	Edmonds 1998
	M			155.4 ± 34.4			
	F			48.9 ± 16.2			
Bristol, Ottawa River, QC	All		0.1 - 1000	23.9		N	Belleau 2008
	M	38.0 ± 5.6		25.4 ± 6.7			
	F	36.6 ± 8.9		20.9 ± 5.2			

Growth and Longevity

The Eastern Musk Turtle becomes more elongated and flattened as it grows. The growth curve for Eastern Musk Turtles is logarithmic and, in Ontario, reaches an asymptote at approximately 25 years of age (Edmonds 1998). Across their North American range, young Eastern Musk Turtles grow at a faster rate than older individuals; and growth rates are lower at higher latitudes (Risley 1933; Mahmoud 1969; Ernst 1986; Edmonds 1998). Growth rates were not significantly different between the sexes in an Ontario population (Edmonds 1998). Male and female turtles reached maturity at 58% and 74% of their maximum body size, respectively (Edmonds 1998). Populations of Eastern Musk Turtles increase in maximum carapace length with increasing latitude and decreasing environmental temperatures (Ashton and Feldman 2003).

Longevity in wild populations is estimated to be from 20-30 years (Ernst and Lovich 2009). Ernst (1986) estimated that two individuals in Pennsylvania, male and female, were at least 27 and 28 years old at the time of their last capture. However, thirty years is probably an underestimate of maximum longevity given the high adult annual survival rate reported from a Georgian Bay population (Edmonds 1998). In captivity, one individual lived for more than 54 years (Snider and Bowler 1992).

Little is known about age-specific mortality in this species. In a Virginia population, annual survival rates in all age and sex groups were estimated at 84-86% (Mitchell 1988). According to Edmonds (1998), the estimated annual survivability rate (the proportion of the population in one year which is present the next year) around Loon Island, Georgian Bay, Ontario, in 1997 was 0.68 (95% CI: 0.54-0.86) for adult males and 0.91 (95% CI: 0.62-1.37) for adult females. The lower rate for males reflects their greater mobility among islands which made their recapture much less likely. In Norway Bay, Québec, along the Ottawa River, Belleau (2008) estimated that adult Eastern Musk Turtle quarterly survivability during the active season varied from 0.79 (95% CI: 0.66-0.88) to 0.99 (95% CI: 0.01-0.99). Sampling bias, potential emigration, and the relatively short time span the data were collected for these estimates (3-4 years) in comparison to this animal's life span mean that these survival rates must be interpreted with caution. Typically, freshwater turtle species have high egg, hatchling and early juvenile mortality rates and exceptionally low mortality rates of adults and older juveniles (Brooks *et al.* 1991; Iverson 1991b; Congdon *et al.* 1993, 1994).

Generation time is approximately 14-20 years. This estimate was obtained using the IUCN calculation for Generation Time (IUCN 2010a), the youngest mature female documented in a Canadian populations of Eastern Musk Turtles (8 years of age; Edmonds 1998), and an estimate of the annual adult mortality rate in a population of Eastern Musk Turtles (16%; Mitchell 1988). Canadian studies (Edmonds 1998) suggest that annual mortality rates in some populations may be substantially lower than 16%.

$$\begin{aligned}\text{Generation Time} &= (1/\text{annual adult mortality rate}) + \text{age of first reproduction}\\ &= (1/0.16) + 8\\ &= 14.25 \text{ years (based on Mitchell 1988)}\end{aligned}$$

$$GT = 1/0.09 + 9 = 20 \text{ years (based on Edmonds 1998)}$$

Equation 1. Calculation of generation time based on IUCN guidelines (IUCN 2010a) and two studies featuring Eastern Musk Turtles (Mitchell 1988; Edmonds 1998).

Interspecific Interactions

Across their range, Eastern Musk Turtles use Beaver and Muskrat lodges for nesting and overwintering (Kiviat 1978; Ernst 1986; Belleau 2008; Ernst and Lovich 2009).

The following epizoic algae have been observed growing on the carapace and plastron of Eastern Musk Turtles: *Basicladia chelonum*, *B. crassa*, *Dermatophyton radians*, *Cladophora kuetzingiana*, *Derepyxis dispar*, *Entophysalis rivularis*, *Lyngbya* sp., *Oscillatoria splendida*, and *Rhizoclonium hieroglyphicum* (Wilson and Friddle 1950; Edgren *et al.* 1953; Neill and Allen 1954; Proctor 1958; Dixon 1960; Belusz and Reed 1969; Mahmoud 1969; Ernst 1986). Turtles are the only known natural host of the freshwater algal species *Basicladia chelonum* and *Basicladia crassa* and the relationship is believed to be commensal (Allee *et al.* 1949; Edgren *et al.* 1953). The proportion of epizootic algae on Eastern Musk Turtles is much higher than that found on other turtles (Edgren *et al.* 1953; Belusz and Reed 1969).

The most common ectoparasites on freshwater turtles are Hematophagus leeches (*Placobdella* sp.) (Sawyer 1986; Watermolen 1996; Light and Siddall 1999). These ectoparasites can cause bacterial and fungal infections, anemia (Frye 1991; Mader 1996), and act as vectors for hemoparasites including *Haemogregarina* sp. (Mann 1962; Telford 1984; Siddall and Desser 2001) and *Trypanosoma* sp. (Mann 1962; Telford 1984). Eastern Musk Turtles are a bottom-dwelling species and they generally have higher ectoparasite loads than other freshwater turtles (Ernst 1986; Ryan and Lambert 2005; McCoy *et al.* 2007). The following ectoparasites have been observed on Eastern Musk Turtles: *Placobdella parasitica* and *P. ornata* (Ernst 1986; Ryan and Lambert 2005; Readel *et al.* 2008). Generally, *Placobdella* sp. feed on turtles in the spring and the number of leeches residing on turtles increases until mid-summer (Ernst 1971; MacCulloch 1981; Readel *et al.* 2008). In the late summer and fall they release from their hosts to reproduce and occasionally return to feed their young and/or attach themselves for winter (Sawyer 1986; Graham *et al.* 1997).

Eastern Musk Turtles can also be parasitized by protozoans (*Myxidium chelonarum* and *Haemogregarina stepanowi*), nematodes (*Spiroxys contortus*), and trematodes (*Hapalorhynchus reelfooti*, *H. gracilis*, *Heronimus chelydrae*, *Pleorchis mollis*, *Polystomoidella oblongum*, *Telorchis medius*, *T. robustus, Trionyx spiniferus,* and *Vasotrema attenuatum*) (Cahn 1937; Byrd 1939; Loftin 1960; Oglesby 1961; Ernst and Barbour 1972; Ernst and Ernst 1979; Platt and Snyder 2007).

Diet

The Eastern Musk Turtle is a bottom-feeding omnivore. It has a highly developed olfactory system (Fadool *et al.* 2001; Murphy *et al.* 2001) and it forages by probing the substrate (soft mud, sand, decaying vegetation) with its head. The Eastern Musk Turtle has an average bite force of 30.72 Newtons (Herrel *et al.* 2002), which allows it to feed on small snails and clams. Large food items are held in the jaws and torn into smaller pieces with the front claws (Harding 1997).

Individuals smaller than 5 cm in straight carapace length feed primarily on small aquatic insects, algae, and carrion. Individuals greater than 5 cm in straight carapace length feed on a variety of food (Ernst and Lovich 2009). Known prey include earthworms (Lumbricidea), leeches (Hirudinea), clams (*Anodonta* sp., *Corbicula fluminea*, *Ligumia subrostrata*, *Pisidium* sp.), snails (*Amnicola* sp., *Campeloma* sp., *Goniobasis* sp., *Helisoma antrosum*, *H. trivolis*, *Leptoxis subglobossa*, *Melanoides tuberculata*, *Oxytrema simplex*, *Physa pumila*, *P. sayi*, *Planorbella duryi*, *Pleurocera uniciale*, *Pomacea paludosa*, *Viviparus georgianus*), amphipods (Amphipoda), isopods (Isopoda), crabs, crayfish (*Orconectes virilis*), spiders (Arachnida), insects (ants (Formicidae), bees (*Apis mellifera*) and wasps, beetles (Coleoptera), butterfly and moth larvae (Lepidoptera), caddisflies (Trichoptera, *Leptocella albida*), crickets and grasshoppers (*Gryllus pennsylvanicus*, *Melanoplus mexicanus*), damselflies and dragonflies (*Anax junius*, *Enallagma* sp., *Leucorrhinia* sp., *Perithemis* sp.), fly and mosquito larvae (Diptera), mayflies (*Caenis* sp., *Hexagenia* sp.) and true bugs (Hemiptera, belostomatids, *Pelocoris* sp., *Ranatra* sp.), fish (eggs, larvae, adults) (*Ameiurus* sp., Catostomidae, *Lepomis gibbosus*, *L. macrochirus*, *Perca flavescens*, Poeciliidae), anurans (tadpoles and adults)(*Lithobates* sp.), filamentous algae (*Chara* sp., *Cladophora* sp., *Oedogonium* sp., *Spirogyra* sp.), parts of higher plants (*Anacharis* sp., *Bidens* sp., *Ceratophyllum* sp., *Cornus* sp., *Eichhornia crassipes*, *Hydrilla* sp., *Ludwigia peploides*, *Najas* sp., *Nuphar luteum*, *Nymphaea* sp., *Potomogeton illinoensis*, *Ranunculus* sp., *Spirodela* sp., *Utricularia* sp., *Vallisneria americana*), and carrion (Surface 1908; Evermann and Clark 1916; Lagler 1943; Penn 1950; Mahmoud 1968; Berry 1975; Bancroft *et al.* 1983; Ernst 1986; Mitchell 1994; Palmer and Braswell 1995; Schneider 1998; Ford and Moll 2004; Iverson and Meshaka 2006; Ernst and Lovich 2009).

Eastern Musk Turtles are prey generalists and prey availability is thought to be the driving force behind regional and seasonal variations in diet composition (Lagler 1943; Mahmoud 1968; Berry 1975; Bancroft *et al.* 1983; Ford and Moll 2004; Ernst and Lovich 2009). Differences in diet have also been observed between males and females. Bancroft *et al.* (1983) found that males, in general, are more dependent on aquatic insects and less dependent on snails than females. Eastern Musk Turtles only feed when water temperatures are between 13 and 35°C (Mahmoud 1969).

Predation

Eggs of Eastern Musk Turtles are eaten by many predators, including Raccoons (*Procyon lotor*), Striped Skunks (*Mephitis mephitis*), various herons (Ardeidae) and crows (*Corvus*), foxes (*Urocyon cinereoargenteus*, *Vulpes vulpes*), and Fishers (*Martes pennanti*) (Harding 1997; Marchand *et al.* 2002; Ernst and Lovich 2009). In the Great Lakes region, Eastern Musk Turtle nest mortality often exceeds 80% (Harding 1997). Although predation is not the sole cause of poor nest success for turtles, it is a limiting factor in many cases (Browne 2003).

Hatchling and juvenile Eastern Musk Turtles are prey for a number of species, including predatory fish (e.g., black bass (*Micropterus sp.*)), American Bullfrogs (*Lithobates catesbeiana*), Northern Watersnakes (*Nerodia sipedon*), Snapping Turtles, and herons (Ardeidae). Juvenile and adult turtles are preyed upon by Red-shouldered Hawks (*Buteo lineatus*), Bald Eagles (*Haliaeetus leucocephalus*), Raccoons, and Fishers (*Martes pennanti*) (Lagler 1943; Bendell 1959; Punzo 1975; Clark 1982; Bancroft *et al.* 1983; Ernst 1986; Ernst *et al.* 1997; Harding 1997; Jordan and Arrington 2001; Punzo and Alton 2002; Ernst and Ernst 2003; Ernst and Lovich 2009). Although there are incidental observations of Eastern Musk Turtles getting trapped in Pondmussels and drowning (Plummer and Goy 1997), the threat posed by *Ligumia nasuta* (a very small and endangered species) and *L. recta* (a larger, more common species) in Canada is unlikely to be significant.

When disturbed or handled, most individuals will attempt to bite and scratch (Ernst and Lovich 2009). When unable to reach their target, turtles will threaten to bite by opening their mouths, or retreat into their shells. Eastern Musk Turtles may also release a yellowish-brown malodorous fluid from four glands (Rathke's glands) located on the underside of the carapacial margin (Logier 1939; Ehrenfeld and Ehrenfeld 1973; Eisner *et al.* 1977). Similar glands are found in all Kinosternids. The odour produced by two of the *w*-phenylalcanoic acids (5-phenylpentanoic and 7-phenylalcanoic) present in the secretions has led to the common name 'Stinkpot' for this species. Eisner *et al.* (1977) speculated that the secretion is used as an aposematic signal to warn aquatic predators of the general undesirability of Eastern Musk Turtles. Due to its high volatility, Ernst and Lovich (2009) suggest that the secretion would be most effective against land and air predators. This secretion may also play a role in courtship and mating by allowing individuals to discriminate the sex of potential mates (Mahmoud 1967; Ehrenfeld and Ehrenfeld 1973; Lewis *et al.* 2007).

POPULATION SIZES AND TRENDS

Sampling Effort and Methods

The most common method of capturing Eastern Musk Turtles consists of active searches along the shoreline in shallow vegetated bays. Although this beast is often described as cryptic because it is small and does not regularly bask out of water, it is easy to capture and sample using well established techniques based on its normal habitat and behaviour. Musk turtles occupy shallow (< 1 m) water about 95 % of their active season, and are visible (i.e., not buried) about 65% of the time in the active season (Edmonds 1998). During the day, Eastern Musk Turtles can be found by flipping lily pads and teasing vegetation as they actively use these habitats to thermoregulate (Edmonds 1998; Carrière and Blouin-Demers 2007; Millar 2008; Laverty 2010; Picard *et al.* 2011). Turtles can also be found during the day by investigating shallow silty areas, logs, and root masses submerged along the shoreline (Gillingwater pers. comm. 2012). Even when they are buried, they can be located by the Brooks' Technique of walking in shallow habitat in waders and feeling for them underfoot. At dawn and dusk, using a canoe, Eastern Musk Turtles can be spotted along the lake/river bottom using a powerful (1 million candles and up) spotlight and caught using a dip net (Belleau 2010). Alternatively, baited hoop nets may be used to catch turtles; however, the use of wings is recommended and is usually associated with a considerable amount of fish bycatch (Browne 2003; Belleau 2010; Larocque *et al.* 2012b). For a breakdown of Eastern Musk Turtle surveys in Ontario and Québec, please refer to the **DISTRIBUTION – Search Effort** section of the report. Long-term mark-recapture studies have produced population size estimates for five Eastern Musk Turtle populations: Grenadier Island in the St. Lawrence River (Carrière 2007; Carrière and Blouin-Demers 2007; Millar 2008; Picard *et al.* 2011), along the north shore of the Ottawa River (Belleau 2008), Point Pelee National Park (Browne 2003); Massasauga Provincial Park in the Georgian Bay (Laverty 2010), and Loon Island also in the Georgian Bay (Edmonds 1998).

Abundance

The Canadian population of Eastern Musk Turtles appears to be divided into scattered sites across southern Ontario (southwestern, central, and eastern), the southeastern edge of northeastern Ontario, and southwestern Québec. Thirty-two census divisions have documented reports of Eastern Musk Turtles dating from 1858 to 2011 (NHIC unpub. data; Table 1).

For this report, recorded sightings were divided into 'populations', geographically or otherwise distinct groups that have little demographic or genetic exchange with other such groups (adapted from IUCN 2001; COSEWIC 2010b). Eastern Musk Turtles are relatively small turtles with limited dispersal ability, especially across terrestrial habitat. Thus, Eastern Musk Turtle populations are thought to be isolated if they are separated by more than 10 km of riverine habitat, 5 km of other aquatic habitat (lakes, marshes, ponds, etc.), and 1 km of land (NatureServe 2010). Based on these criteria, the collection of Eastern Musk Turtle sighting records in Canada represents 113 'populations'.

There are limited data available to estimate the overall size of the Canadian population of Eastern Musk Turtles. Thus, out of necessity, the overall estimate of population size is crude. Although one population size estimate exceeds 1400 mature individuals (Massasauga Provincial Park) (Laverty 2010), most populations appear to be much smaller (84 to 295 individuals) (Browne 2003; Carrière and Blouin-Demers 2007; Belleau 2008; Millar 2008) (Table 3). The minimum population size estimate for Canada is 9500 individuals; this was calculated by taking the smallest reported population size estimate (84 individuals) and multiplying by the number of known 'populations' in Canada (113 'populations') and rounding up to the hundreds. This number underestimates the minimum population size as there are still areas of this species' Canadian range that have not been adequately surveyed and targeted surveys in suitable habitat have often resulted in the identification of new populations. It is reasonable to conclude then that the total number of mature individuals exceeds 10,000.

Table 3. Eastern Musk Turtle, *Sternotherus odoratus*, population size estimates and sex ratios (male: female) for five sites in Canada.

Site	Year	Population Size	95% Confidence Intervals	Sex Ratio (M:F)	Population Density	Source
Grenadier Island, St. Lawrence River	2007	233	189, 314	2:1		Carrière and Blouin-Demers 2007
	2008	241	207, 341	3:2		Millar 2008
Loon Island, Georgian Bay	1997	264 (M) 117 (F)	185, 328 71, 186	1:3.6		Edmonds 1998
Massasauga Provincial Park, Georgian Bay	2009	1440	±633	1:1 *(impacted sites)* male biased *(non-impacted sites)*	17.9 turtles/ha *(impacted sites)* 6.5 turtles/ha *(non-impacted sites)*	Laverty 2010
Norway Bay, Ottawa River	2006	295	206, 467	1.7:1	4.1 turtles/ha	Belleau 2008
Point Pelee National Park, Point Pelee	2002	84	± 76.8	1:1		Browne 2003

Fluctuations and Trends

In Canada, since the last COSEWIC status report, 36 new Eastern Musk Turtle 'populations' have been identified (33% of all Eastern Musk Turtle populations based on reported sightings) and two census divisions have been added to this species' extent of occurrence (Table 1, Figures 4, 5). This increase, however, does not reflect an increase in abundance or range. Undoubtedly, Eastern Musk Turtles have historically been in these areas and undetected or unreported. Eastern Musk Turtles behave "cryptically" in that they do not bask aerially and are small relative to other turtles, so they are not normally observed unless one deliberately searches for them (Bendell 1959; Lamond 1994). Since the last report, several targeted surveys have been completed (see **DISTRIBUTION – Search Effort**) and best-practices techniques for Eastern Musk Turtles capture have been established (e.g., Belleau 2010). These factors, in turn, are responsible for the large number of newly identified 'populations'.

Generally, low recruitment and a short active season seem to be important factors limiting populations of this species across its Canadian range (Edmonds and Brooks 1996; Browne 2003; Belleau 2008). Unfortunately, most mark-recapture studies on Eastern Musk Turtles in Canada are short term (less than 3 years; Browne 2003; Carrière 2007; Millar 2008; Picard 2008; Laverty 2010) and inferences about individual population trends and fluctuations are limited.

In Ontario, declines in Eastern Musk Turtle populations have been observed (southwestern Ontario and Golden Horseshoe) and, in more remote locations, are inferred based on known threats (e.g., fisheries bycatch) (Bancroft *et al.* 1983; Edmonds and Brooks 1996; Edmonds 2002; Browne 2003; Laverty 2010; Larocque *et al.* 2012a). Of the 29 census divisions in Ontario that have recorded sightings, eight (28%) have not reported sightings since 1986 (Table 1, Figures 4, 5). At least three other divisions have had few records over that same period (Toronto, Hamilton, Kent, Table 1) despite searches and a large human population as potential observers. Therefore, it is not unreasonable to infer that the species has been extirpated or become nonviable in these areas. Added to the eight census divisions with no observations since 1986, one can infer a 34 % (11 of 32 census divisions) decline over less than two generations. Furthermore, 36 of the 109 identified 'populations' (33 %) of Eastern Musk Turtles in Ontario are based solely on sightings reported prior to 1986. In areas experiencing intense agricultural activity and increasing urban development (see **HABITAT - Habitat Trends**) (e.g., Brant, Essex, Toronto, Chatham-Kent, Middlesex, Haldimand-Norfolk, Halton, Niagara, Hamilton, Peel, Durham), habitat loss, alteration, and fragmentation may be causing historical Eastern Musk Turtle populations to decline. Indeed, the lack of recent sightings in southwestern Ontario census divisions, in light of habitat trends and considerable search effort, may reflect local extirpations. For example, DeCatanzaro and Chow-Frazer (2010) reported that Eastern Musk Turtles were absent from degraded wetlands in the lower great lakes (Erie and Ontario) that fell within their historical range. Despite recent (2003-2011) dedicated surveys (hundreds of person-hours) in the Long Point Area and Rondeau Provincial Park (along the north shore of Lake Eerie), no live Eastern Musk Turtles were found (Gillingwater and Brooks 2001; Gillingwater and Piraino 2004, 2005; Gillingwater pers. comm. 2012). These data suggest that this species is now extirpated from its historical range in Haldimand-Norfolk. Furthermore, habitat modification combined with intense fishing is thought be the cause of the near extirpation of the Eastern Musk Turtle around the city of Hamilton (Lamond 1994).

The above "losses" have occurred over less than two Eastern Musk Turtle generations, but lack of recent sightings does not necessarily reflect declining populations or local extirpations of all populations that lack recent records. For example, it is likely that Eastern Musk Turtles are still extant, despite lack of recent observations, where habitat is abundant and there is little human disturbance (e.g., Georgian Bay North-East (French River Provincial Park)). In such areas, if no major threats exist (i.e., high adult mortality due to direct and indirect anthropogenic activities), populations are most likely to be stable, even if limited or non-targeted surveys fail to detect musk turtles.

Currently, musk turtles still exist in southwestern Ontario in a strip of Lake Huron coastline and associated dune, wetland and forest surrounded by heavily utilized farmland in the Port Franks-Ipperwash area. They occur in at least three small ponds in Port Franks and in part of the old Ausable Channel (Gillingwater, pers. comm. 2012), Pinery Provincial Park has one or two recent sightings. The species also persists in Point Pelee National Park, where a small number of musk turtles inhabit a handful of sand ponds and marsh habitat, with the park otherwise bordered by Lake Erie and farm fields. Long Point has only three relatively recent records. Extensive surveys of Long Point NWA and wetlands on the tip, yielded no other observations (1996-1999, 2004-2006) (Gillingwater pers. comm.2012). Finally, a small number of records exist from the Detroit River near Windsor and Walpole Island on Lake St. Clair. Despite repeated searches for years, none appear to remain in Rondeau Provincial Park (Gillingwater pers. comm. 2012). Similarly, musk turtles appear extirpated from the Thames River. In most of these sites, Eastern Musk Turtles are usually found in dunes/sand spits/sand bottomed ponds exist that are in constant flux, via erosion, changes in current etc. This flux leaves the sites less apt to become heavily overgrown by succession. Unfortunately, all these sites are being inundated by Common Reed which is destroying these last pockets of suitable habitat for the Eastern Musk Turtle (see: **THREATS AND LIMITING FACTORS**: *Non-native Species*).

Declines in some of the Frontenac/ Canadian Shield populations may also be inferred based on the high rates of fisheries bycatch and other sources of mortality in these areas (see **THREATS AND LIMITING FACTORS**). Given the impact of increases in adult mortality on Eastern Musk Turtle populations, the high mortality rates associated with fisheries bycatch are likely to lead to population declines in certain waterways.

There are not enough data to determine Eastern Musk Turtle population trends in Québec. Three of the four populations of Eastern Musk Turtles found in Québec were discovered after the last status report was released (Edmonds 2002).

Rescue Effect

The possibility exists for Eastern Musk Turtles to repopulate Ontario and Québec from the United States. The Rescue Effect is likely dependent on the following: 1) the persistence of Michigan, Vermont, and New York populations of Eastern Musk Turtles adjacent to Canadian populations, 2) sufficient immigration and reproduction of individuals dispersing across the Detroit River, St. Clair River, Niagara River, Richelieu River, St. Lawrence River, Lake Erie, and Lake Ontario, and 3) whether turtles arriving by open water have access to suitable aquatic (residential) and terrestrial (nesting) habitat. Most immigrants would have to cross large bodies of water (e.g., Lake Erie, Lake Ontario, St. Lawrence River) to reach Canadian lands. The flexible metabolism of ectothermy, however, may pre-adapt reptiles for waif dispersal (e.g., rafting, swimming) and several examples exist of reptiles that would have had to cross 1-14 km to reach 'oceanic' islands in the upper Great Lakes (King 1988).

Although the Michigan and Ontario populations of Eastern Musk Turtles are morphologically similar (Reynolds and Seidel 1983) and Eastern Musk Turtles are ranked "secure" in Michigan, it is unlikely that re-colonization will occur naturally from Michigan as Eastern Musk Turtles have not been recorded in areas adjacent to Canadian populations (Lagler 1943; Michigan DNR 2001; NHIC unpub. data).

In Vermont, the Eastern Musk Turtle is ranked "imperiled" yet immigration from the Champlain Valley population (Vermont DFW 2005; VRAA 2011) may be possible through the Champlain Lake and the Richelieu River into Québec. Eastern Musk Turtles were observed in 2009 inhabiting a stream connected to the Richelieu River in Québec (AARQ unpub. data).

New York populations of Eastern Musk Turtles along the St. Lawrence River (New York State DEC 2007) may be able to re-colonize Canadian populations of Eastern Musk Turtles. Eastern Musk Turtles are found in many sites along the Frontenac Arch/St. Lawrence River. Due to the proximity of these areas to the United States, they may represent important immigration/ emigration routes between the American and Canadian populations of Eastern Musk Turtles. Eastern Musk Turtles are considered 'Secure' in New York (NatureServe 2010).

It is unlikely that declining Canadian populations will greatly benefit from an influx of new individuals if these individuals are not protected from the threats triggering these declines. Given that human population and resource consumption are continuing to increase and the two greatest risks to Eastern Musk Turtle population persistence are habitat loss and decreased adult survivorship due to anthropogenic activities, successful rescue is not likely.

THREATS AND LIMITING FACTORS

Like all native turtle species in Canada, Eastern Musk Turtles are limited primarily by their life-history strategy (late maturity, long lifespan, low recruitment, and reliance on low adult mortality) (see BIOLOGY Life Cycle and Reproduction) and cool, relatively short, active seasons. These limiting factors are not in themselves threats to turtles, but in concert with anthropogenic activities, these factors make turtles unusually vulnerable to a host of threats. Because of climate, high human densities, and habitat alteration over most of their Canadian range, Eastern Musk Turtle populations in Canada are particularly vulnerable to stochastic mortality events and to chronic increases in mortality rates of both juveniles and adults. The recovery period compensating for this increased mortality is likely to be long, as documented for other freshwater turtle species in Canada (Brooks *et al.* 1988, 1991; Congdon *et al.* 1993, 1994; Cunnington and Brooks 1996; Galbraith *et al.*1997; Heppell 1998). These slow recovery rates are attributed to low rates of recruitment, extended juvenile periods (late maturity), and lack of any apparent density-dependent responses (i.e., low density, increased food availability, etc., do not lead to increases in survival, growth rate, egg or clutch size (Brooks *et al.* 1991; Keevil *et al.* 2011).

Habitat Destruction and Alteration

One of the most significant threats to Eastern Musk Turtle populations is habitat destruction and alteration (e.g., land conversion, shoreline development, dam placement, and dredging and draining of waterways and wetlands (Ernst and Lovich 2009)). Anthropogenic activities in or around areas inhabited by turtles often result in habitat loss, degradation and fragmentation. DeCatanzaro and Chow-Frazer (2010) reported Eastern Musk Turtles absent from degraded wetlands in the lower Great Lakes (Erie and Ontario) that fell within their historical range, but reached high abundances in marshes of Georgian Bay and the North Channel, Sudbury District, a region with relatively low human disturbance.

Firstly, increased human traffic in natural areas results in destruction of natural vegetation, and garbage which attracts nest and hatchling predators such as Raccoons, Striped Skunks and Red Foxes (*Vulpes vulpes*) (Smith and Engeman 2002; Spencer and Thompson 2005; Browne and Hecnar 2007). Subsidized predators can drastically impact prey populations because food subsidies insulate predator populations from effects of declines in prey populations (Sinclair *et al.* 1998). Thus, the density of a predator population may rise above levels that would occur without the additional resources (Sinclair *et al.* 1998). In 2008 and 2009, Laverty (2010) observed higher rates of adult Eastern Musk Turtle mortality in sites affected by recreational activities compared to undisturbed sites and attributed these findings partly to subsidized mammalian predators. Subsidized predation is also associated with increased nest predation, decreased hatchling survival, increased female mortality, and altered female nesting behaviour in several freshwater turtle species (Garber and Burger 1995; Boarman 1997; Klemens 2000; Marchand and Litvaitis 2004; Browne and Hecnar 2007). In the Port Franks area, for example, 11 adult female Eastern Musk Turtles were killed by mammalian predators at a known oviposition site (Gillingwater unpub. data). Typically, in most freshwater turtle species, hatchling and juvenile mortality rates are much higher than adult mortality rates. Unnaturally high levels of nest predation or adult mortality, however, brought on by unusually abundant) populations of predatory species (e.g., Raccoons), represent an important limiting factor to the recovery of this species.

Secondly, anthropogenic barriers (e.g., dams, roads, agriculture) may lead to habitat fragmentation by decreasing turtle dispersal ability (Rizkalla and Swihart 2006; Bennett *et al.* 2010). Eastern Musk Turtles are vulnerable to desiccation when they are out of water (Ernst 1968) which further limits their dispersal in fragmented landscapes.

Thirdly, natural shorelines possess more emergent and aquatic vegetation than developed shorelines (Radomski and Goeman 2001), and these habitat configurations are crucial to Eastern Musk Turtles throughout the active season (Picard *et al.* 2011). Shoreline development may also eliminate Eastern Musk Turtle nesting sites which are limited, particularly in the cooler parts of the species' Canadian range, which is now where the great majority of the population occurs.

Finally, drainage of a common hibernation site can kill a large proportion of a population of Eastern Musk Turtles. For example, the drainage of a canal in Ohio caused approximately 450 hibernating Eastern Musk Turtles to die (Thomas and Trautman 1937).

Chronic Mortality (Anthropogenic Sources)

Another significant threat to Eastern Musk Turtles is increased rates of chronic mortality due to anthropogenic activities and urbanization (e.g., fisheries bycatch, motor boat and fishing mortality/injuries, road mortality). Water-based activities (i.e., fishing, power boating) can affect freshwater turtles by causing behaviour disruptions, injuries, and mortalities (Bancroft *et al.* 1983; Garber and Burger 1995; Borkowski 1997; Galois *et al.* 2002; Horne *et al.* 2003; Carrière 2007; Galois and Ouellet 2007; Bulté *et al.* 2010; Laverty 2010; Larocque *et al.* 2012a, b). Hoop or fyke nets set by inland commercial fisheries or researchers lead to Eastern Musk Turtle bycatch and are an important source of mortality (Larocque *et al.* 2012a, b). As water temperatures increase during summer, the length of time turtles can stay submerged underwater decreases exponentially (Herbert and Jackson 1985). Hoop nets, for either commercial fishing or research, are often deployed in warmer months in areas inhabited by Eastern Musk Turtles. Typically, the nets are completely submerged and left for over 24 h before being checked (Larocque *et al.* 2012a, b). Thus, turtles can enter these nets and drown (Barko *et al.* 2004; Larocque *et al.* 2012a, b). In two Ontario lakes, Larocque *et al.* (2012a) reported Eastern Musk Turtle bycatch rates of approximately 1% using tandem commercial hoop nets. Most captured turtles were adults and despite the provision of an air space in the nets, Larocque *et al.* (2012a) documented severe turtle mortality (33% in one lake). In addition to drowning in submerged hoop nets, Eastern Musk Turtles are frequently captured on baited fish hooks and in hoop nets. These turtles are often killed by fishermen or perish from injuries/infections caused by hooks (Mahmoud 1969). Habitat modification, combined with intense fishing is thought be a cause of the extirpation of Eastern Musk Turtles around the city of Hamilton (Lamond 1994).

Eastern Musk Turtles are at a greater risk of significant injury from boats. Eastern Musk Turtles bask at the surface and can be severely wounded or killed by propellers and boat hull impacts (Bancroft *et al.* 1983; Edmonds 1998). In a Florida population of Eastern Musk Turtles, motorboat traffic was a major source of mortality (Bancroft *et al.* 1983). In Massasauga Provincial Park, Ontario, lower Eastern Musk Turtle abundance and higher mortalities were recorded in areas with recreational activity compared to undisturbed sites (Laverty 2010). Similarly, in Point Pelee National Park, Ontario, Eastern Musk Turtles were considerably less abundant in areas impacted by anthropogenic activities (Browne 2003).

Although Eastern Musk Turtles rarely move significant distances over land, they are at high risk of road mortality when they do cross roads due to their small size and awkwardness on land (Crowley pers. comm. 2012; Millar pers. obs.). In 2010, three Eastern Musk Turtles were found dead on the Thousand Islands Parkway as part of a long-term road mortality study. Of the 4845 total road kills along the Thousand Islands Parkway in 2010, 1.7% of these were turtles (Garrah pers. comm. 2011). Furthermore, females may be at greater risk of injury because of their movements while nesting (Marchand and Litvaitis 2004; Aresco 2005; Gibbs and Steen 2005; Carrière 2007; Galois and Ouellet 2007; Beaudry *et al.* 2008; Bulté *et al.* 2010). The subsequent loss of mature females could lead to important population declines (Congdon *et al.* 1983; Garber and Burger 1995).

Pollution

Due to their long life span, turtles may build up high levels of environmental toxins (e.g., organochlorine pesticides, methylmercury, PCBs, dioxins, and furans) in their tissues (Hall 1980; Bishop *et al.* 1991; Golet and Haines 2001; de Solla *et al.* 2008). These toxins can have serious effects on their health and breeding ability (Bishop *et al.* 1991, 1998; de Solla *et al.* 2008; Rowe 2008). Eastern Musk Turtle populations occurring in the Great Lakes, and their connecting channels and inland locations, may be exposed to high PCB levels as this contaminant is the main cause of consumption restrictions on sports fish (>80% of restrictions) in these areas, followed by mercury (2-20% of restrictions) (OME 2011). To date, however, no information is available on contaminant levels in Eastern Musk Turtles across their Canadian range and the effects of contaminants (organic substances, inorganic substances, pesticides, and others) on Eastern Musk Turtle health and reproduction are unknown. Reduced hatching success and increased deformity rates in Snapping Turtles and Eastern Spiny Softshell Turtles (*Apalone spinifera*) in contaminated areas have been reported in a number of Ontario ecotoxicology studies (Bishop *et al.* 1991, 1998; de Solla *et al.* 2008). Additionally, Crews *et al.* (1995) noted that PCBs can alter Painted Turtle population structure by reversing gonadal sex at otherwise male-producing temperatures. Pesticides and other pollutants may also indirectly impact Eastern Musk Turtles by adversely affecting populations of sensitive Eastern Musk Turtle prey species, such as clams and snails (Ernst and Lovich 2009).

Diseases

Disease outbreaks reduce survival and can have potentially severe effects on turtle populations. A necrotic shell disease has been reported in Virginia Eastern Musk Turtles (Ernst *et al.* 1999). The biological agent of the damage has not been identified although Ernst *et al.* (1999) suggest that the damaged tissues may be the result of secondary infections following an initial chemical insult damaging the skin and shell scutes. The necrotic shell disease has not been reported for Eastern Musk Turtle populations in Canada, but has been reported in Snapping Turtles and Painted Turtles (Brooks pers. comm. 2012).

Unsustainable Use

The Eastern Musk Turtle is not listed in the Convention on International Trade in Endangered Species (CITES) database and, currently, there are no international trade regulations for this species. In the United States, from 2003 to 2005, a total of 56,395 Eastern Musk Turtles (31% of them wild caught) were exported (Senneke 2006). These numbers represent declared exports and total numbers may be much higher in light of illegal trafficking of wild caught individuals. Little is known on the volume of exports for this species in Canada, although it is presumably lower than that of the United States. The collection, trade, and possession of this species is illegal under federal and provincial legislation.

Eastern Musk Turtles have been sold illegally in Ontario and advertised on online classifieds such as Kijiji (Gillingwater pers. comm. 2011; Millar pers. obs. 2011; Miller pers. comm. 2012; Zacher pers. comm. 2012). From May 2008 to March 2012, there have been at least 26 official investigations by the Ministry of Natural Resource relating to illegal internet sales of Eastern Musk Turtles in Ontario (Miller pers. comm. 2012; Zacher pers. comm. 2012). Despite protective legislation, commercial reptile wholesalers are going to great lengths and risk to import this species into Canada, suggesting a high demand for Eastern Musk Turtles, from neonates to adults. Thus, the pressure from the pet trade may lead to illegal and unsustainable collection of wild Eastern Musk Turtles (Miller pers. comm. 2012). Long-term studies indicate that turtles, due to their slow rate of maturation and low reproductive success, cannot withstand commercial and private collection (Congdon *et al.* 1993, 1994; Garber and Burger 1995). Turtle harvesting usually continues at a given location until supplies are exhausted or until it is no longer profitable (Miller pers. comm. 2012). Past studies indicate that removal of modest numbers of adults and older juvenile freshwater turtles can have deleterious and lasting effects on populations (Congdon *et al.* 1993; Garber and Burger 1995).

Global Climate Change

The overall impact of global climate change on Eastern Musk Turtles remains unclear. In Canada, at the northern extreme of this species' global range, increases in temperature may enable range expansion. Janzen (1994) suggests, however, that global increases in temperature of at least 4°C may eliminate male hatchling production and that increases of less than 2°C may still dramatically skew sex ratios. Furthermore, turtle egg and hatchling survival are highly vulnerable to temperature extremes and periods of unusually high rainfall or drought. Because Eastern Musk Turtles nest close to the shoreline (Lindsay 1965; Ernst 1986; Edmonds 1998), abnormally high water levels after the nesting season may drown eggs. In periods of drought, Gibbons *et al.* (1983) observed a decrease in the survival and reproductive output of Eastern Musk Turtles.

Non-native Species

In some areas of their range, wetland sites are becoming increasingly invaded by *Phragmites australis* subsp. *australis* and other non-native plant species. *Phragmites a. australis* in particular is overtaking entire wetlands, changing species diversity, topography and limiting prey species, altering foraging habitat, oviposition habitat and in general changing the entire shoreline ecosystem (Willcox *et al.* 2003; Gillingwater and Piraino 2004; Badzinski *et al.* 2008; Gillingwater 2009). Rondeau Provincial Park, Long Point National Wildlife Area, Big Creek National Wildlife Area and parts of Port Franks are just a few of the areas that are experiencing dramatic declines in species diversity and loss of habitat (Willcox *et al.* 2003; Gillingwater and Piraino 2004; Gillingwater 2005, 2009; Badzinski *et al.* 2008). In the Port Franks area, past oviposition sites have been completely lost to 4 m-high stands of non-native *Phragmites*, forcing female Eastern Musk Turtles to utilize smaller sections of shoreline habitat for egg laying. The extent of habitat loss is increasing dramatically each year as non-native *Phragmites* become better established (Gillingwater 2005; Gillingwater unpub. data). Other non-native plants have less obvious negative effects (e.g., European Frogbit, *Hydrocharis morsus-ranae*), and further study is necessary to determine long-term consequences of these relatively new invasions (Gillingwater and Piraino 2004; Gillingwater 2009).

Alteration of the littoral zone by the Grass Carp (*Ctenopharyngodon idella*), a herbivorous freshwater fish often used for aquatic weed control, has been directly linked to dramatic decreases in Eastern Musk Turtle populations (Bancroft *et al.* 1983). As selective grazing by Grass Carp removed most of the near-shore Illinois Pondweed (*Potamogeton illinoensis*) beds, Eastern Musk Turtles shifted to alternate habitats, especially Wild Celery (*Vallisneria Americana*) and bare substrate (Bancroft *et al.* 1983). Sterile Grass Carp have been used for aquatic weed control in Alberta and Saskatchewan, but this practice is illegal in Ontario unless authorized by the appropriate authority. Only a few individuals have been found in the Great Lakes, presumably bought from the live fish food markets and released (Cudmore and Mandrak 2004). By altering habitat and competing with other herbivorous species, Grass Carp can impact water quality, aquatic flora and fauna, and wildlife species in Canada (Cudmore and Mandrak 2004).

Locations

For this report, recorded sightings were divided into 'locations', geographically or ecologically distinct areas in which a single threatening event can rapidly affect all individuals of the taxon present (IUCN 2001; COSEWIC 2010b). Eastern Musk Turtles are relatively small turtles with limited dispersal ability and are thought to be isolated if they are separated by more than 10 km of riverine habitat, 5 km of other aquatic habitat (lakes, marshes, ponds, etc.), and 1 km of land (NatureServe 2010). Furthermore, due to delayed sexual maturity and low reproductive success, Eastern Musk Turtle populations rely on high yearly adult survivorship (>80%). Thus, high local adult mortality due to a threatening event (e.g., winterkill due to drainage of communal hibernacula) can have devastating consequences on an Eastern Musk Turtle population. As populations are, by definition, considered to have little demographic exchange with each other, immigration is unlikely to offset the loss of a high percentage of mature individuals from another Eastern Musk Turtle population. For these reasons, populations of Eastern Musk Turtles identified in this report were also considered 'locations'. Based on the criteria above, Eastern Musk Turtle records in Canada represents 113 'locations' (see **POPULATION SIZES AND TRENDS – Abundance** section).

PROTECTION, STATUS, AND RANKS

Legal Protection and Status

The Eastern Musk Turtle was assessed as 'Threatened' by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) in 2002, by the Committee on the Status of Species at Risk in Ontario (COSSARO), and by the 'Ministère des Ressources naturelles et de la Faune du Québec (MRNF).

The Eastern Musk Turtle is listed as 'Threatened' under Schedule 1 of the *Species at Risk Act* (SARA, S.C. 2002, c. 29) and is thus afforded federal legal protection in Canada. This act prohibits the killing, harming, harassing, capturing, possessing, collecting, buying, selling, and trading of Eastern Musk Turtles and prohibits the damage or destruction of the residence of one or more Eastern Musk Turtles on federal lands and waters. SARA also requires protection for this species' critical habitat, once identified, within federal jurisdiction. This requirement may be applied to provincial or private lands if provincial legislation or other measures are not already in place to protect the species, and if cooperative stewardship measures fail.

In Ontario, the Eastern Musk Turtle is listed as a 'specially protected reptile' under Schedule 9 of the *Fish and Wildlife Conservation Act* (S.O. 1997, c. 41). The Eastern Musk Turtle is also listed as 'Threatened' under Schedule 4 of Ontario's *Endangered Species Act* (S.O. 2007, c. 6) (ESA). Thus, it is illegal to kill, harm, harass, capture, take, possess, transport, collect, buy, sell, lease, trade or offer to buy, sell, lease or trade wild Eastern Musk Turtles in Ontario. Furthermore, under the ESA (S.O. 2007, c. 6), starting on June 30th, 2013, it will be illegal to damage or destroy the habitat of Eastern Musk Turtles in Ontario.

In Québec, the Eastern Musk Turtle is listed as 'Threatened' under the 'Loi sur les espèces menacées ou vulnérables' (*Act respecting threatened or vulnerable species*) (R.S.Q., c E-12.01) (MRNF 2011) and is afforded protection under the 'Loi sur la conservation et la mise en valeur de la faune' (*Act respecting the conservation and development of wildlife*) (LCMVF) (R.S.Q., c. C-61.1). Under article 26 of the LCMVF (R.S.Q., c C-61.1), it is illegal to disturb, destroy, or damage the eggs or nest of an animal. It is also prohibited to capture, hunt, and/or keep in captivity any species of turtles that are native to Québec. The aquatic habitat of Eastern Musk Turtles in Québec is also indirectly protected by Article 128.6 of this same act (R.S.Q., c. C-61.1). Because the Eastern Musk Turtle is a primarily aquatic species, the 'Loi sur la qualité de l'environnement' (*Environment Quality Act*) (R.S.Q., c. Q-2) generally and more specifically, through the 'Politique de protection des rives, du littoral et des plaines inondables' (*Protection Policy for Lakeshores, Riverbanks, Littoral Zones and Floodplains*) (R.S.Q., c. Q-2, a. 2.1), protects this species' aquatic habitat.

The Eastern Musk Turtle is not protected under the United States' *Endangered Species Act* of 1973 (16 USC 1531 - 1544). The import, export, sale, receipt, acquisition, transport, and purchase of wild Eastern Musk Turtles (alive or dead, and any part, product, egg, or offspring) already taken, possessed, transported, or sold in violation of state, federal, American Indian tribal, or foreign laws, or regulations that are fish or wildlife-related, however, is illegal in the United States under the *Lacey Act* of 1900 (16 USC 3371 - 3378).

There are two national Recovery Strategies pertaining to Eastern Musk Turtles: the Canadian Multi-Turtle Recovery Strategy (Ontario and Québec): Northern Map Turtle (*Graptemys geographica*), Spiny Shoftshell (*Apalone spinifera*), Blanding's Turtle (*Emydoidea blandingii*), Stinkpot (*Sternotherus odoratus*), and Spotted Turtle (*Clemmys guttata*) (SARA Responsible Agency 20YY) and the National Recovery Strategy for Species at Risk in the Thames River Aquatic Ecosystem (NRSSARTRE) (The Thames River Recovery Team 2010). The draft Canadian Multi-Turtle Recovery Strategy (Ontario and Québec) is currently under review and a document outlining the criteria to be used to identify Critical Habitat for Eastern Musk Turtles is being prepared. The NRSSARTRE has been published and describes the distribution of aquatic species at risk in the watershed, habitat quality issues, and threats to species at risk (The Thames River Recovery Team 2010). The Thames River Recovery Team aims to reduce the impacts of altered water flow and to enhance or restore water quality and aquatic habitat by reducing siltation, nutrient loadings and toxic contamination (The Thames River Recovery Team 2010). As of the publication of this status report, no national action plans have been prepared.

In Ontario, the Ontario Multi-Species Turtles at Risk Recovery Team has prepared a draft Ontario Multi-Species Turtles at Risk Recovery Strategy. In Québec, the Recovery Plan for Five Turtle Species: the Wood Turtle, the Northern Map Turtle, the Blanding's Turtle, the Eastern Musk Turtle, and the Spotted Turtle has been published (ERTQ 2005). The Québec Recovery Plan enumerates 28 actions centred on research, protection of turtles and their habitat, and public outreach.

Non-Legal Status and Ranks

In Canada, the Eastern Musk Turtle is ranked 'Vulnerable' (N3) (NatureServe 2010). In Ontario and Québec, the Eastern Musk Turtle is ranked 'Vulnerable' (S3) and 'Critically Imperiled' (S1), respectively (NatureServe 2010). In the United States, the Eastern Musk Turtle is ranked 'Secure' (N5) (see **Technical Summary** for state ranks). Globally, the Eastern Musk Turtle is ranked 'Secure' (G5) (NatureServe 2010). No information on the conservation status of Eastern Musk Turtles was found on the IUCN red list (IUCN 2010b).

Habitat Protection and Ownership

Approximately 234.22 km^2 (17%) of the index of area of occupancy of the Eastern Musk Turtle in Canada is within protected areas (e.g., National Parks, Provincial Parks, Conservation Areas, National Wildlife Areas, NGO Nature Reserves, Areas of Natural and Scientific Interest). Federal lands where Eastern Musk Turtles occur and federal lands that are upstream of Eastern Musk Turtle sightings are enumerated in Table 4. At present, no data are available to determine conclusively whether or not the existing protection afforded the species within Canada is sufficient for the species to persist. Given that only 17% of the IAO is within protected areas and the main threat to this species is habitat destruction and alteration; however, it is unlikely that the present level of protection is sufficient.

Table 4. Federal lands where the Eastern Musk Turtle occurs and federal lands that are upstream of Eastern Musk Turtle sightings.

Name	Federal Department	Province
Long Point National Wildlife Area	Environment Canada	Ontario
St. Lawrence Islands National Park	Parks Canada	Ontario
Georgian Bay Islands National Park	Parks Canada	Ontario
Point Pelee National Park	Parks Canada	Ontario
Rideau Canal National Historic Site	Parks Canada	Ontario
Trent Severn Waterway National Historic Site	Park Canada	Ontario
CFB/ASU Petawawa	Department of National Defence	Ontario
Former Camp Ipperwash	Department of National Defence	Ontario

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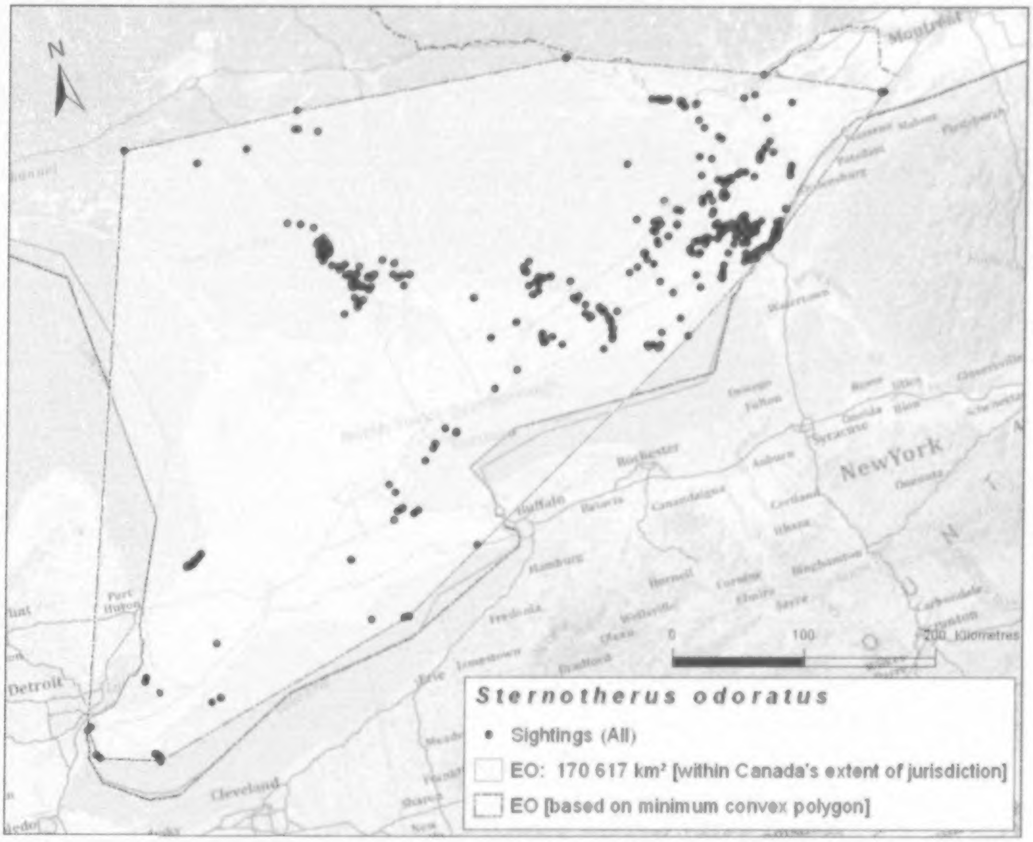
BIOGRAPHICAL SUMMARY OF REPORT WRITER

Catherine S. Millar completed her B.Sc. and M.Sc. at the University of Ottawa working with herptiles. In 2008 and 2009, while completing her M.Sc. field work, Catherine worked in cooperation with the St. Lawrence Islands National Park (SLINP) to monitor the Eastern Musk (*Sternotherus odoratus*), Northern Map (*Graptemys geographica*), and Blanding's (*Emydoidea blandingii*) turtle populations in SLINP. At the time of submission of this report, Catherine was the first author of three articles pertaining to chelonian ecology published in peer-reviewed scientific journals.

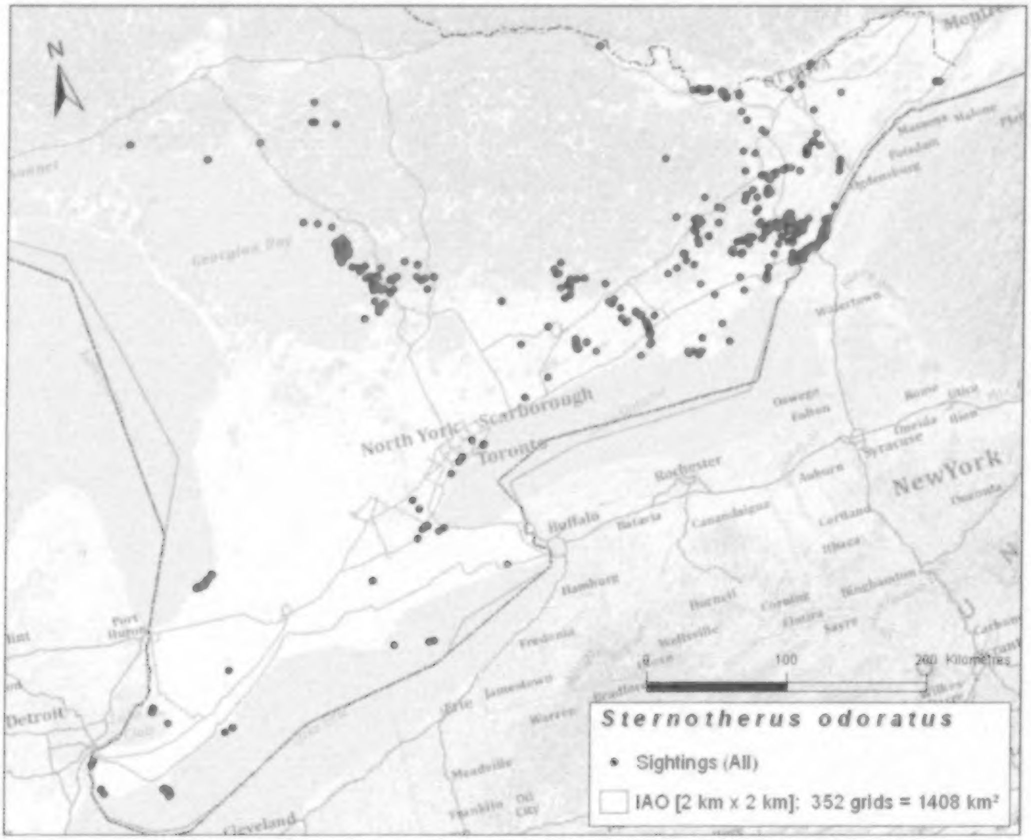
COLLECTIONS EXAMINED

The Museum of Nature's Eastern Musk Turtle collection catalogue was reviewed to acquire sighting information but no specimens were examined.

Appendix 1. Extent of occurrence (EO) using both historical and recent Eastern Musk Turtle sightings in Canada. The minimum convex polygon used to calculate EO was clipped within Canada's extent of jurisdiction. The EO calculations and the corresponding map were provided by Jenny Wu, Environment Canada, 2012.


N
Montreal
Watertown
Rochester
Syracuse
New York
Buffalo
Batavia
Port Huron
Detroit
Cleveland
Erie
0
100
200 Kilometres
Sternotherus odoratus
● Sightings (All)
EO: 170 617 km² [within Canada's extent of jurisdiction]
EO [based on minimum convex polygon]

Appendix 2. Index of area of occupancy (IAO) of the Eastern Musk Turtle in Canada using both recent and historical sightings and a 2 x 2 km grid. The IAO calculation and the corresponding map were provided by Jenny Wu, Environment Canada, 2012.


N
Georgian Bay
North York
Scarborough
Toronto
Buffalo
Rochester
Syracuse
New York
Watertown
Ottawa
Detroit
Port Huron
Cleveland
Erie
0
100
200 Kilometres
Sternotherus odoratus
● Sightings (All)
☐ IAO [2 km x 2 km]: 352 grids = 1408 km²